VOLUME 57 [W. B. No. 1003] NUMBER 12

MONTHLY WEATHER REVIEW

DECEMBER, 1929

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UNITED STATES DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
WASHINGTON, D. C.

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MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 57, No. 12
W. B. No. 1003

DECEMBER, 1929

CLOSED FEBRUARY 3, 1930
ISSUED MARCH 1, 1930

PROFESSOR EXNER ON THE CIRCULATION OF COLD AND WARM AIR BETWEEN HIGH AND LOW LATITUDES [1]

By ALFRED J. HENRY

[Condensed from a translation by W. W. Reed]

In continuation of his earlier work (Über die Zirkulation zwischen Rossbreiten und Pol, Meteorolog. Zeitschr., 1927, p. 46). Professor Exner now gives us the results of his studies on the subject above indicated. In the introductory statement it is pointed out that on account of the deflecting force of the earth's rotation there can not be anywhere in the hemispheres a simple circulation to carry the large amounts of heat from tropical to polar regions. The simple streaming of cold air masses toward the Equator and above this of warm masses toward the North, possible in the equatorial region, must divide as high latitudes are reached into several circulations which lie side by side on a circle of latitude. Thus on account of the rotation of the earth there can be no simple circulation oblique to a parallel; at a place on the same parallel one must expect a cold current from the polar region, beside it a warm current from the tropical region, and beside the latter a cold current again and so on.[2]

It is further indicated that in the Northern Hemisphere a warm northward flowing current can persist only when there exists a pressure gradient toward the west and in like manner a cold current from the north can persist only when there exists a pressure gradient toward the east, thus, for example if a cold current oblique to a parallel lies west of a warm current then between the two there must be a region of low pressure, and if now a cold current lies east of a warm current then there is necessarily high pressure between them so that from the number of high and low pressure regions on a parallel we may obtain the number of circulations.

Since the cyclones and anticyclones change in intensity and direction of progression from day to day, it follows that the circulations referred to do not maintain themselves in a uniform manner but continually appear to move from place to place. These currents are therefore not to be considered as constant; their manner of change from one place to another has not been determined either empirically or theoretically.[3]

The author assumes that the circulations act in a way somewhat analogous to that of a fluid, water for example, since in very large dimensions the gases through the effect of gravity become more similar to fluids than in small dimensions.

As set out in his earlier work, he looks upon them only as an effect of solar energy which produces a circulation between cold and warm regions and not as wave-like oscillations at the boundary between a region of warm equatorial air and a region of cold polar air, as the polar-front theory has designated it. In this sense the *cyclones and anticyclones are to be viewed as secondary effects of the circulation; they obtain their energy from the vigorous force of a circulation, and this vigorous force originates in the supply of heat to the lower latitudes and the withdrawal of heat from the higher latitudes.*

OBSERVATIONAL MATERIAL

In order to gain a clearer knowledge of the circulations between lower and higher latitudes Professor Exner investigated the temperature conditions at 120 stations in the Northern Hemisphere for a series of 90 days, January 1 to March 31, 1910, without a consideration of the concurrent pressure distribution. Instead of using absolute temperatures he computed the departure of the current temperature from the normal for each day of the period, and these values with proper sign attached were plotted on charts of the Northern Hemisphere. He further separated the regions of cold and warm by lines of zero departure, thus isolating the regions of positive and negative temperature departure, respectively. It was found that these regions often had the form of strips or bands oriented in a north/south direction, thus agreeing with the before-mentioned assumption. The period chosen was the year 1910, because since that time the Russian yearbooks have not appeared. The great region between Europe and eastern Asia is especially important in investigations of this character.

The winter months were chosen since the currents are more active in winter than in summer. The individual daily departures were obtained by means of a graph that showed the daily march of temperature for the year.

After isolating regions of positive and negative anomaly, respectively, those regions having departures of plus or minus 5°, 10°, 15°, and 20° C. were indicated. By reason of lack of stations in the polar regions and over the southern part of the North Pacific, the charts are incomplete for those regions.

The cold currents move for the most part toward southern latitudes and the warm currents toward the pole. It was found, however, that it was not always possible to relate every cold current to a high latitude source, as when a cold current from the north is intersected by a warm current from the south, thus permitting a remnant of the cold air mass to persist for some time until finally its temperature is raised.

The charts show that for the most part regions with departures of 10° or more C. lie in higher latitudes; it was also found that abnormally warm and abnormally cold

[1] Über die Zirkulationen kalter und warmer Luft zwischen hohen und niedrigen Breiten. Sitzungsberichten der Akademie der Wissenschaften in Wien, Abt. IIa, 137 Band, 3 und 4 Heft 1928.

[2] In many respects this concept is similar to Bigelow's counter current theory.—EDITOR.

[3] As the author points out they follow and evidently are dependent upon changes in intensity of cyclones and anticyclones however these may be brought about.—EDITOR.

currents lie often close to one another; and it is also remarked that the two kinds of currents have essentially the direction of a meridian which corresponds to the view of the circulations mentioned at the outset. In the polar regions there are almost always several meridional currents of cold and warm air, one can not therefore look upon the polar air as a cold mass continuously in repose and divided from the warm southern air by a stationary polar front, but one must assume that the cold air from the polar region flows into the tropical region and the warm currents in the opposite direction.

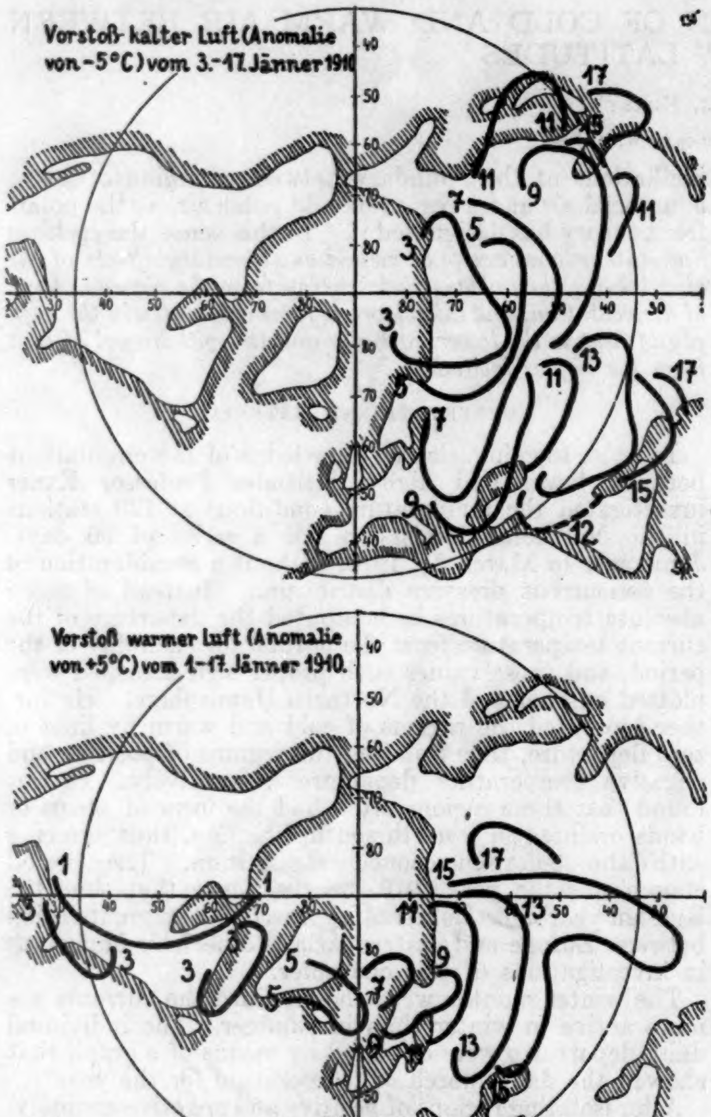
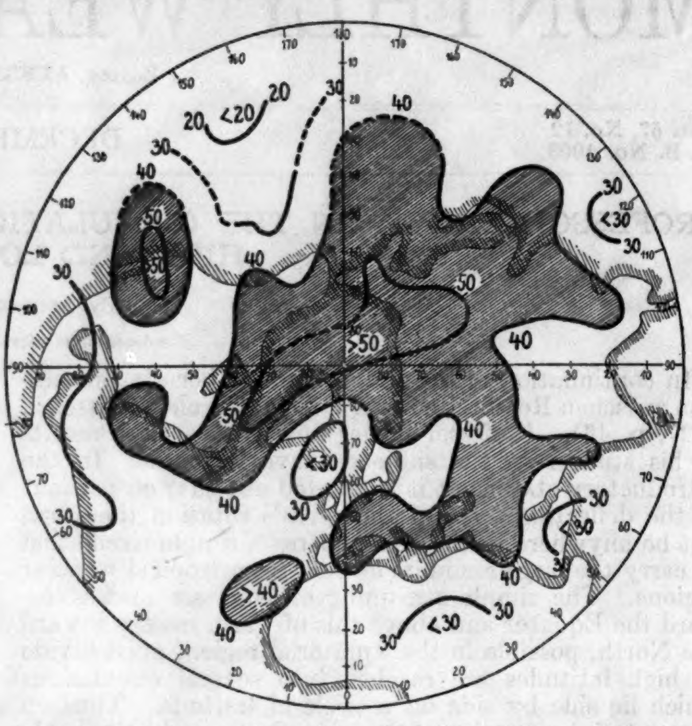


FIGURE 7.—Advance of cold air (anomaly −5° C.) January 3-17, 1910, and (below) advance of warm air (anomaly +5° C.) January 1-17, 1910

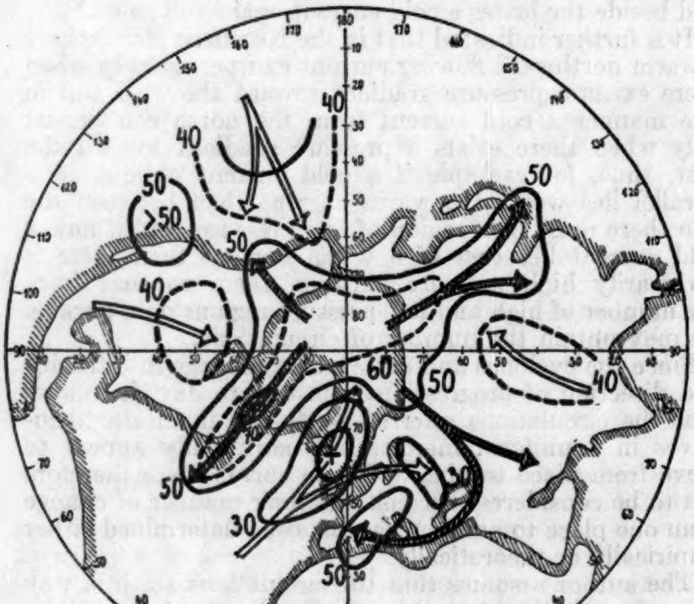
It is often noted in the charts that the warm currents have a direction toward the northeast, not directly toward the north. Also from one day to the next the zone of greatest warmth often migrates eastward; likewise the cold zones move most frequently eastward and with this they naturally have movement toward the south; they often migrate after the warm zones toward the east with the result that they are displaced more to the southward than those and thus in connection with the warm zones bring about movement in the cyclonic direction.

Occasionally there also occurs a movement of the cold zones toward the southwest. The phenomena thus manifest from the temperature charts are wholly in agreement with our knowledge of cyclones and anticyclones. If,



Häufigkeit der kalten Strömungen während der 90 Tage vom 1/I.-31/III. 1910.

FIGURE 8.—Frequency, in percentage, of the cold currents during the 90-day period from January 1 to March 31, 1910



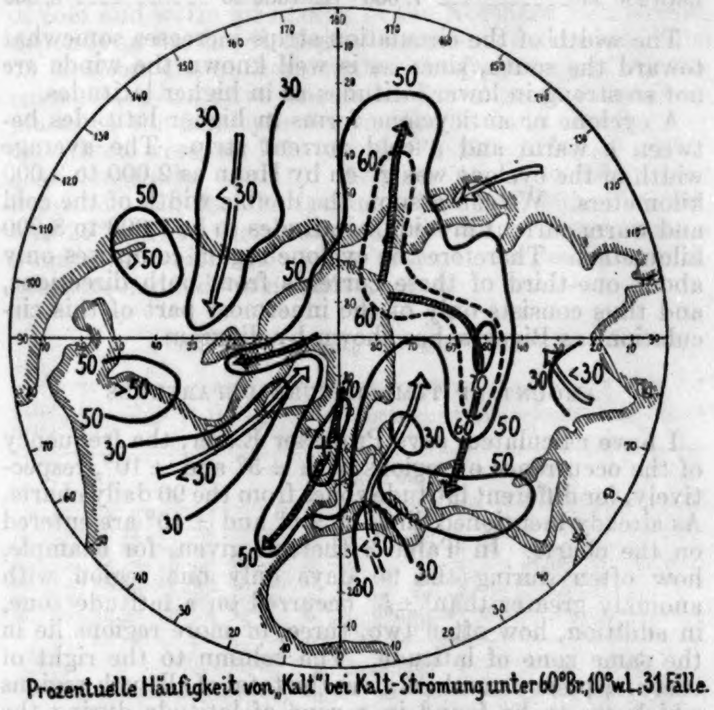
Prozentuelle Häufigkeit von „Kalt" bei Warm-Strömung unter 60° Br., 10° w.L., 49 Fälle.

FIGURE 9.—Frequency, in percentage, of "Cold" with warm current in latitude 60° N. and longitude 10° W.; 49 cases

therefore, the phenomenon of the great length of warm and cold zones exceeds the conditions for the individual cyclones and anticyclones, we have to expect that at the boundary of two currents directed essentially in the line

of a meridian there occasionally form cyclones and anticyclones, respectively. In this sense one can conceive the Bjerknes idea of the "cyclone family" where several cyclones form, one behind the other, as the effect of a cold current on the west and a warm current in the east, as appeared for example in Asia on the charts for March 16–18 (not reproduced). * * *

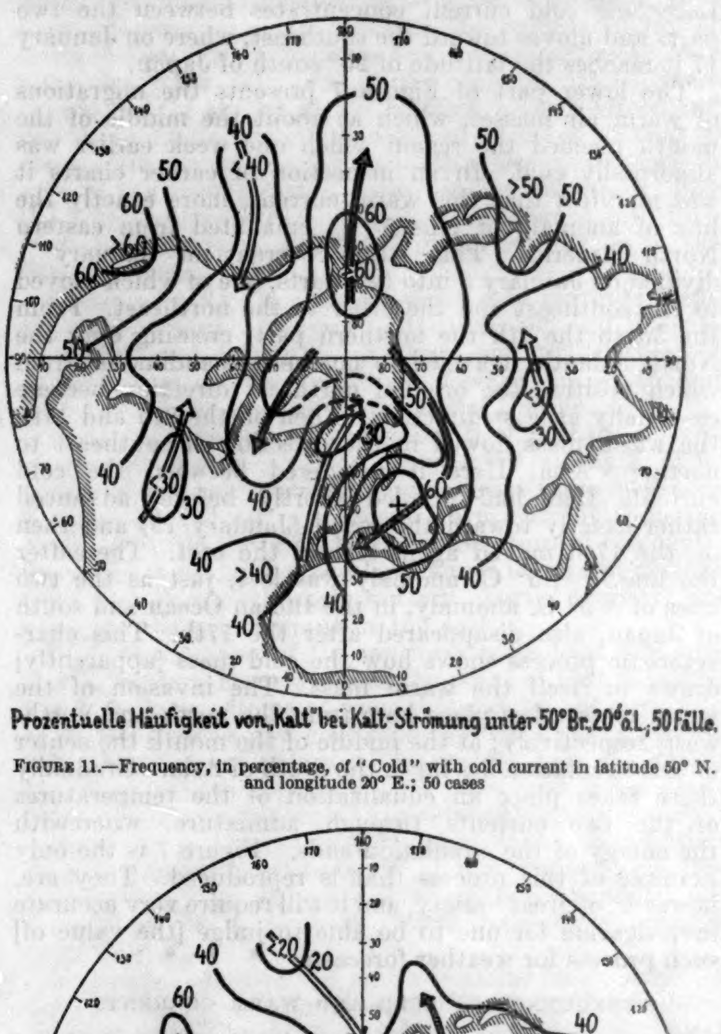
From among the 90 daily charts Professor Exner selected for discussion those of March 16–21, Figures 1–6 (not reproduced), since during these days there were marked changes in the number of circulations. In high latitudes there was seen in the beginning three circulations, then two circulations, and lastly but a single circulation. The frequency of the circulations on all of the 90 days will be discussed later; it may be remarked here that the center of the circulation, cold source to which warm currents flow and from which the cold currents flow off, must naturally not be solely in the polar regions; this would be the case if the earth had an entirely uniform surface, since in winter the pole would



Prozentuelle Häufigkeit von „Kalt" bei Kalt-Strömung unter 60°Br, 10°w.L., 31 Fälle.

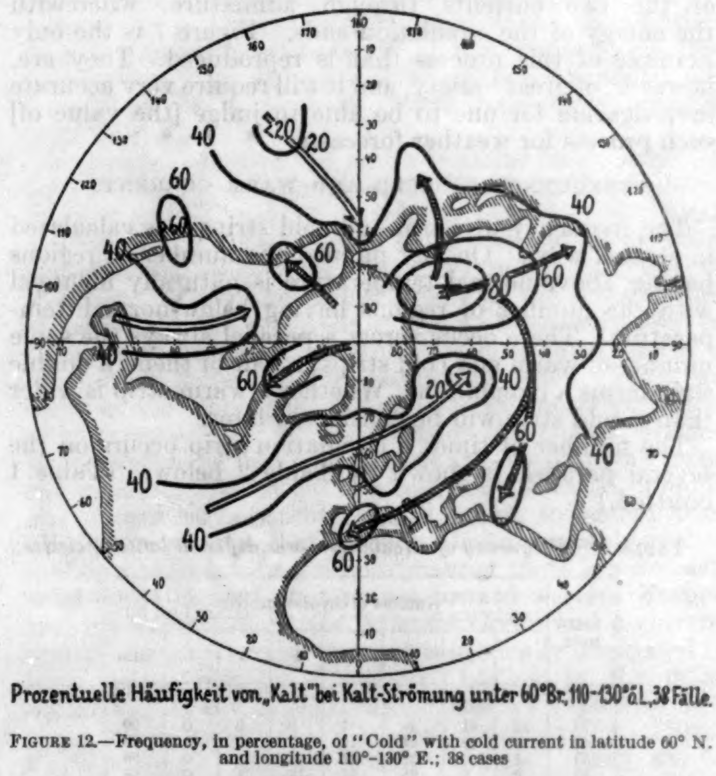
FIGURE 10.—Frequency, in percentage, of "Cold" with cold current in latitude 60° N. and longitude 10° W.; 31 cases

then be the coldest place on the earth. We must add to the region of the cold source the continental regions lying far north, the northern part of North America, Greenland, and especially northern Asia. Since in the circulation the warm currents always have the tendency to approach the region of the cold source where through radiation the air pressure falls aloft, so not only the pole is to be looked upon as the direction of the warm currents and the center of the circulation, but, for example, also northern Asia whither in Figures 1–6 the warm currents of eastern Europe gradually drift. As an example of such current phenomena Figure 7 (original numbering is followed) is presented. This figure shows the outspreading of a mass of cold air from northern Asia and the inflow into this cold region from January 1 to 17. Here are given the lines of temperature anomaly of 5° C. in the direction of movement on the Northern Hemisphere during the 17 days, and the cold and warm currents are represented separately on two charts. The upper chart of Figure 7 shows the outspreading of the cold mass. On January 3 the line of −5° C. lies in northern Asia. In the following days up to the 7th it spreads toward south, southwest, and southeast (the



Prozentuelle Häufigkeit von „Kalt" bei Kalt-Strömung unter 50°Br, 20°ö.L., 50 Fälle.

FIGURE 11.—Frequency, in percentage, of "Cold" with cold current in latitude 50° N. and longitude 20° E.; 50 cases



Prozentuelle Häufigkeit von „Kalt" bei Kalt-Strömung unter 60°Br, 110–130°ö.L., 38 Fälle.

FIGURE 12.—Frequency, in percentage, of "Cold" with cold current in latitude 60° N. and longitude 110°–130° E.; 38 cases

charts give the position of the lines every other day). On the 9th the cold current begins to separate into two parts; the one migrates toward southeastern Europe and the other toward eastern Asia. The first current turns back from the west and moves toward the south,

it reaches the Red Sea on the 13th and northern India on the 15th. The second current separates on the 11th into two parts of which one stretches toward the east (Japan) and the other toward the south (South China). Later the cold current concentrates between the two parts and moves toward the southeast, where on January 17 it reaches the latitude of 20° south of Japan.

The lower part of Figure 7 presents the migrations of warm air masses, which at about the middle of the month reached the region which one week earlier was abnormally cold. In an inspection of earlier charts it was manifest that this warm current, more exactly the line of anomaly of plus 5° C. emanated from eastern North America. This warm current of January 1 divided on January 3 into two parts, one of which moved to the southeast and the other to the northeast. From the 3d to the 7th the northern part, crossing over the North Atlantic, traveled to northern Scandinavia, from which position the original northeast direction became essentially an east direction. Then on the 9th and 11th the warm mass flowed in the direction of southeast to northern Asia. Here it wandered between the cold currents that had divided shortly before, advanced rather exactly toward the south (January 15) and then on the 17th moved again toward the east. Thereafter the line of +5° C. anomaly was lost, just as the two lines of −5° C. anomaly, in the Indian Ocean and south of Japan, also disappeared after the 17th. This characteristic process shows how the cold mass [apparently] draws to itself the warm mass. The invasion of the warm mass takes place here from the north and northwest, respectively; at the middle of the month the center of this circulation lies far in the south of Asia. Gradually there takes place an equalization of the temperatures of the two currents through admixture, wherewith the energy of the circulation ends. Figure 7 is the only example of this process that is reproduced. They are, however, of great variety, and it will require very accurate investigation for one to be able to judge [the value of] such process for weather forecasts. * * *

FREQUENCY OF COLD AND WARM CURRENTS

The frequency of warm and cold strips was calculated in several ways. On any parallel the number of regions having above-normal temperature is naturally identical with the number of regions having below-normal temperature. There occur across a parallel always the same number of warm and cold strips; a pair of them, a double strip forms a circulation. Whether a warm strip is wider than a cold strip will be considered later.

The number of times a circulation strip occurs on the several parallels is shown by Table 2 below. (Table 1 omitted.)

TABLE 2.—*Frequency of circulations over different latitude circles*

Latitude	Number of circulation strips							
	1	2	3	4	5	6	7	Sum
°								
70	10	51	28	1	0	0	0	90
60	1	19	57	11	2	0	0	90
50	1	6	32	41	9	1	0	90
40	0	8	25	37	19	1	0	90
30	0	7	20	32	20	11	0	90
20	0	1	14	29	32	12	2	90
Sum.	12	92	176	151	82	25	2	540

In latitude 70° two circulations appear most frequently, in latitude 60° three circulations, in latitude 50°, 40°, and 30° four circulations as may be seen from the table.

The frequency distribution of the circulation strips in a given latitude can be used to estimate how wide on the average is a circulation strip. The circumference of a parallel $U = 2r\pi \cos\phi$ (r = radius of the earth; ϕ = latitude) divided by the number of circulation strips gives the width. But since the number of circulation strips is rather different on the 90 days we obtain a most advantageous idea if we evaluate the frequency of the different strip numbers in percentages. We apply for the latitude B of a circulation strip the following equation which according to Table 2 holds for latitude 70

$$B = \frac{u}{90}\left(\frac{10}{1} + \frac{51}{2} + \frac{28}{3} + \frac{1}{4}\right)$$

In this way there result for the different latitudes the following width of circulation strips:

	Kilometers		Kilometers
Latitude 70°	6, 900	Latitude 40°	8, 700
Latitude 60°	7, 240	Latitude 30°	9, 200
Latitude 50°	7, 660	Latitude 20°	8, 800

The width of the circulation strips increases somewhat toward the south, since as is well known the winds are not so strong in lower latitudes as in higher latitudes.

A cyclone or anticyclone forms in higher latitudes between a warm and a cold current strip. The average width of the cyclone was given by Hann as 2,000 to 3,000 kilometers. We can assume the double width of the cold and warm current in middle latitudes to be 7,000 to 8,000 kilometers. Therefore the cyclone region comprises only about one-third of these currents from both directions, and thus consists only of the innermost part of this circulation, as Bigelow has shown by diagram.

AMOUNT OF TEMPERATURE DEPARTURES

I have calculated, says Professor Exner, the frequency of the occurrence of regions with ±5° and ±10°, respectively, for different latitude zones from the 90 daily charts. As already mentioned, lines of ±5° and ±10° are entered on the charts. In Table 3 there is given, for example, how often during the 90 days only one region with anomaly greater than ±5° occurred on a latitude zone, in addition, how often two, three, or more regions lie in the same zone of latitude. The column to the right of these frequency numbers gives the total of all such regions which are to be found in a zone of latitude during the 90 days.

TABLE 3.—*Frequency of regions of anomaly of ±5°, ±10°, respectively, in different latitude zones*

Latitude	Number of occurrences of anomaly, regions									
	1	2	3	4	5	Sum	1	2	3	Sum
	>5°						>10°			
>70..	47	31	5	0	0	124	28	7	0	42
70-60..	12	56	18	4	0	194	45	16	2	83
60-50..	7	30	36	15	2	245	42	11	3	73
50-40..	11	45	28	5	1	210	35	5	1	48
40-30..	39	35	10	1	0	143	16	0	0	16
30-20..	42	24	1	1	0	97	2	0	0	2
	>−5°						>10°			
>70..	41	34	5	0	0	124	32	4	1	43
70-60..	18	41	25	5	0	195	40	16	0	72
60-50..	15	38	29	6	0	202	37	5	1	50
50-40..	28	33	19	6	0	175	20	1	0	22
40-30..	52	14	6	1	0	102	12	0	0	12
30-20..	33	10	0	0	0	55	6	0	0	6

These totals give for the regions with anomaly over 5° or more, the greatest frequency in the latitude zone between 60° and 50°; this great frequency extends in similar manner up to 70° and southward to 40°.

The anomalies of greater intensity (more than ±10°) occur most frequently in the region between 70° and 60°. They have one-third to one-fourth the frequency of those of ±5°.

The total number of warm anomaly regions is somewhat greater than that of the cold anomaly regions. This rests on the fact that in higher latitudes cooling is for the most part more intense than warming; the greater number of the smaller positive anomalies gives approximately the same departure from the previously mentioned curve of temperature march as the smaller number of large negative anomalies.[4]

DISTRIBUTION OF COLD CURRENTS OVER THE NORTHERN HEMISPHERE

In order to determine in what way current distribution of cold and warm air masses in the Northern Hemisphere depends on the distribution of continents and oceans, thus on location, the author counted the frequency of the occurrence of negative anomalies for a great number of places in the hemisphere from the 90 daily charts. For this there were used 36 points 0°, 10°, 20° . . . . 170° east longitude and 10° 20°, ... 180° west longitude and for the latitudes 70°, 60°, 50°, 40°, 30°, and 20°. Thus there resulted for each of these places a number of which shows how often in 90 cases the temperature anomaly is negative.

TABLE 4.—*Frequency of negative anomalies*

Latitude	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°	160°	170°	180°
									East half										
°																			
70	30	37	40	41	39	48	45	41	42	45	50	54	53	51	53	52	46	45	----
60	29	37	38	34	32	39	41	39	41	45	46	54	48	52	44	43	44	49	----
50	43	41	50	31	36	47	43	44	44	46	37	46	47	42	44	45	49	44	----
40	48	37	44	41	41	44	42	37	36	34	39	48	45	42	39	37	47	45	----
30	38	38	37	37	45	38	39	40	33	36	38	39	42	42	40	39	44	45	----
20	32	31	26	31	40	30	32	42	37	35	43	40	29	43	41	39	38	36	----
									West half										
70	---	28	31	36	41	44	50	58	56	49	50	46	49	47	44	48	44	43	44
60	---	31	28	34	38	45	52	48	40	41	39	37	44	45	41	31	37	42	44
50	---	37	32	37	41	46	42	38	37	37	35	33	35	33	38	29	31	36	43
40	---	36	37	30	31	41	40	37	41	37	37	51	45	35	30	27	28	33	40
30	---	35	45	38	33	33	33	43	41	34	39	45	57	45	34	23	23	33	40
20	---	35	39	42	37	31	30	35	36	27	25	35	37	48	30	17	18	22	33

The difference of this frequency relative to 90 then gives approximately the positive anomalies, thus the warm currents. To be sure it not rarely happens that a zero line on the daily chart passes through a selected point or very near it. These cases are to be considered as either positive or negative; their frequency amounts, it is estimated, to ten times in 90 cases. If this amount is subtracted from the difference mentioned there is obtained a better, although not entirely certain result for the frequency of the positive anomalies.

The frequencies of the cases of cold are given in Table 4. Each value is related to the total of 90 (not percentages). The values in Table 4 are shown graphically in Figure 8 where the regions with frequency above 40 are shaded.

[4] Since the cyclical trend of a short period such as 90 days may be an important consideration the results of a longer period will be required to definitely determine whether positive or negative anomalies are the most prevalent.—EDITOR.

Here it is shown at once which regions of the polar area cause the most frequent outrushes of cold or cold currents into lower latitudes. First of all there are the regions of Baffin Bay, between Labrador and Greenland, and of northwestern Asia (frequency over 50 in 90 days, thus over 56 per cent). In addition the regions in higher latitudes with least frequency are of importance; they give the most frequent warm currents. Here there stands first of all the region between eastern Greenland and Scandinavia, with a frequency of 30 out of 90; that is, the eastern part of the North Atlantic Ocean; the eastern part of the Pacific Ocean shows similar conditions, only the warm currents here do not push forward into high latitudes [due to geographic-barriers] as they do in the North Atlantic.

Striking features are the frequent cold currents along the east of North America to latitude 30° and likewise that along east Asia to South China, and further the cold current from northwestern Asia toward the south and then toward the west into continental Europe.

The form of this current is similar to that of the current of eastern North America, only more strongly bent. North of this cold current from the east there advances between 50 and 60° a frequent warm current from the North Atlantic through the Baltic Sea toward the continent, and in altogether similar manner the warm current from the Pacific through western North America approaches the cold current in the east.

Both at the point of the southwestward bent cold current in western Europe and at the point of that in North America there adjoins at some distance on the west side of the continent a new cold zone over the Canary Islands and over South California. In middle Asia (longitude 80° to 90°) there appears a third zone with rather great frequency of warmth, which lies between the frequent cold currents from eastern and western Asia. In addition there are found in latitude 20° at very many places frequently less than 30 out of 90; negative anomalies are much more rare in the south than in the north, as appears from Table 3.

In general, Figure 8 represents to us the basic, although only average, current forms on the Northern Hemisphere. We see an outbreaking of cold masses from the polar regions in a direction toward southwest and an invasion of warm masses into high latitudes in the direction of northeast. The latter lie principally on the eastern sides of the oceans, the invasions of cold lie to the westward of these warm currents. Only in Asia does there appear a third warm current in the continental region. When we think of the warm current from Iceland northward it is to be expected that in its circulation this current divides to the westward and to the eastward, cools in the polar region and then flows out as a cold mass toward Labrador and toward Nova Zembla, or still farther to eastern Asia. The warm current that reaches Alaska probably makes similar divisions. In a similar manner there is a division in the cold current that moves toward western Europe into a current toward the Atlantic Ocean and a current toward Africa whereby the cold is gradually dissipated in these warm regions. Therefore, neither in the polar region nor in the tropical region can we expect to find sharp division-surfaces (lines of discontinuity—*Translator*) between cold and warm currents. They are to be assumed only in the intermediate region, where neither the warm source nor the cold source plays a significant rôle, but where the cold and warm masses pass one over the other.

The author has constructed four charts (figs. 9–12) which give the frequency of cold currents on those days

when, at a given place in the Northern Hemisphere, a cold or warm current prevailed. Therewith is given a statistical relation of a chosen current at a (given) place to the currents in other regions of the hemisphere. In Figure 8 it was to be seen that cold currents rarely occur in high latitudes at 10° west longitude. He therefore first selected the days on which there appears a warm current in latitude 60° and longitude 10° west; there are 49 such cases. For these calculations were made relative to how often negative temperature anomaly appears at each tenth degree of latitude and longitude, and these frequency values were reduced to *percentage* values of the 49 cases. The result of this calculation is given by lines of equal frequency in Figure 9. The selected point, with warm current only (60° N., 10° W., having frequency of cold current 0 per cent), is indicated on the chart by a cross.

From the lines in Figure 9 it is seen that very frequently a cold current exists *west* of the warm current; the maximum, over 70 per cent, lies in the same latitude at 60° west longitude, the distance of the middle of the cold stream from the middle of the warm stream is 2,780 kilometers from which there is given the approximate diameter of the cyclone normal to that region. In striking manner there appears further the frequency of cold current in eastern Asia, about half way around the earth from the first point. In the northern part of this region the frequency is over 60 per cent; thus it appears that with a warm current west of northern Europe there generally occurs a cold current in eastern Asia. A third such region appears over northwestern Canada, and a fourth, less marked, over Nova Zembla. Rather intense warm currents are found north of Honolulu toward Alaska and besides in eastern Europe. At the same time there are some regions with now a cold current (greater than 50 per cent) and now a warm current (less than 40 per cent). Thus, for example, with marked warm current in the eastern Atlantic there forms over southwestern Europe a cold zone rather than a warm zone, while over north Germany and the Baltic Sea an offshoot of the warm current moves toward the east. The arrows that are entered on the chart give a probable form of the most frequent currents. In general, we find here four warm and four cold currents which depend on the positions of the continents and the oceans.

The second case (fig. 10) concerns the frequency of cold currents in the hemisphere under the condition that at the same place that is mentioned above (60° N., 10° W.) not a warm but a cold current prevails. For this there are found out of 90 days only 31. At the point marked by the cross the frequency is 100 per cent. This cold current in the east of the Atlantic Ocean goes far to the south. There is found connected with it frequent cold current in middle Asia (greater than 70 per cent), to the east of Asia (greater than 60 per cent), and in addition in 80° west longitude. At the same time there lie between these currents three zones with frequent warm current (cold less than 30 per cent), west as well as east of the main cold current, in the western part of the Atlantic and from Africa to northeastern Europe. The third reaches from the eastern part of the Pacific to North America. In addition there are individual smaller zones with greater or lesser frequency, which may be in part plainly connected with the main currents. If we compare the arrows of Figure 10 with those of Figure 9 we find many similarities, substantially a shifting of the currents of Figure 9 toward the east. The outbreak of cold air from Asia toward the southwest appears in both figures, likewise the tendency of the warm current in Europe toward northern Russia and the tendency of the warm current in the Pacific toward the west of North America.

In a third chart (fig. 11) there is represented the frequency of negative anomalies under the condition that a cold current prevails in 50° N., 20° E. (near Vienna). This condition occurs on 50 days, Figure 11 shows the percentage-frequency of cold; the cross indicates 100 per cent. Here we find substantially three cold currents, the first main current from northern Asia to middle Europe; the second, over Kamchatka into the Pacific Ocean; the third, over Baffin Bay and Greenland. Nowhere in the more distant regions does the frequency amount to 70 per cent. However, the lines, especially those for 50 per cent, are rather unsymmetrically developed so that there exist connections between the currents in the distant regions. An intense warm current passes over the eastern part of the Atlantic and on over Iceland and North Cape in Europe. A second current crosses North America and a third lies in Asia. A striking feature is the cold zone in California with over 60 per cent. It can not be stated whence this cold current originates. Apparently there are individual, inclosed zones of greater or lesser cold frequency occasionally connected with the cold currents, so that we can draw for them no stream arrows as normal directions.

Figure 12 shows, in conclusion, the frequency of negative anomalies under the condition that cold prevails in eastern Asia in latitude 60° and between 110° and 130° east longitude (38 cases). Here we see in the main a rather large region with over 80 per cent frequency of negative anomaly which extends with 60 per cent frequency to latitude 40°. In most striking contrast to this cold zone is a long warm current which is directed from the Atlantic toward northeast and then east to north Asia where, in latitude 70° the frequency falls below 20 per cent. This intense warm current from a rather great distance to northern Asia indicates an interesting form of circulation. When the great cold region lies not in the vicinity of the pole but in eastern Asia then the warm current from the south of the North Atlantic Ocean does not migrate toward the pole but more toward the east. In similar manner, although not so plainly, the warm current in the Pacific appears to be directed toward the northwest, that is, toward the great cold region and not, as usually (always), toward the north or northeast. Indeed, at this time there is a cold region in the northeastern part of the Pacific. In general we find here substantially three cold and three warm currents. The chief zone of cold in eastern Asia spreads out to the south and the east and probably very far to the west as is indicated by the arrows reaching to Spain.

The asymmetry of the frequency lines is very striking in these four cases, so there must exist real connection of the currents to the conditions established. However, it may be pointed out in this connection that in the course of all cases, that is, in the 90 days, there are certain regions with rather great frequency and others with rather small frequency. From this the percentage values under the four separate conditions stand out at many places always as rather great and other places as rather small, as for example, there is on all charts rather great frequency in California [5] and rather small frequency in Honolulu. Nevertheless, the frequency had to be related to the number of the separate condition-cases and not to the frequency-values of each place, since, otherwise, the rela-

[5] The frequency in California is more apparent than real. Coastal stations are used and these are subject to fluctuations of temperature due to a change in wind direction, from the ocean to the land and vice versa; moreover both January and February, 1910, were abnormally cold months in Pacific coast States.—EDITOR.

tion of the frequency of the cold currents of (at) one place to the frequency at another place would not have been expressed.

The concluding chapter of Professor Exner's work is a theoretical discussion of warm and cold currents; naturally it is almost wholly mathematical and therefore not susceptible to further abridgment.

I conclude this review with a translation of the author's final comments on the theory of warm and cold currents as discussed in Chapter V:

Naturally the constancy of the pressure gradient is only a simplified assumption, which does not hold exact in the individual phenomena. The result of calculation indicates that the warm current, which initially was directed northward, soon acquires a component toward the east, that thus the warm current normally maintains a deflection toward northeast.

Through this deflection the pressure gradient toward the west is increased on account of the suction effect of the mass toward the east, thus the stationary equation can come to hold again, but the direction of movement is now shifted somewhat toward the right. In the cold current from the north the pressure gradient eastward is diminished by acceleration of the mass toward the east, so that then also, after the beginning of a southeasterly current direction, the stationary equation can come to hold again. A theoretical calculation of these two currents and their directions has not yet succeeded, however, in conjunction with the preliminary simple representation of the acceleration toward the east, it may be pointed out that the warm currents actually show for the most part, a deflection toward the east of the direction of the pole, and that the cold currents after migrating from the polar region push their easterly masses, for the most part, to the east, while the western portion of the cold current proceeds, for the most part, toward the south or to the southwest and west.

Very frequently the cold current divides into two parts after it has passed the cyclonic center lying to the east. The warm currents also occasionally divide toward northeast and northwest, whereby the latter part circles the cyclone in the east (?—*Translator*). In addition to the cause given, which consists in the change of deflective force, these phenomena are naturally connected with the change in pressure gradient.

We must assume that, between the cold current in the west and the warm current in the east, the low pressure at the limiting surface is farther diminished by whirl formation (turbulence) and centrifugal force, whereby the cyclone originates (fig. 13—not reproduced—Ed.). Conversely at the border between the cold current in the east and the warm current in the west an anticyclonic whirl can come into existence.

The cyclonic whirl advances along the lines between the warm and cold currents, and, in general in the direction of the warm current. The reason for this may lie in part in the fact that on account of less friction at the ground (not so much in contact with the ground—*Translator*) the warm current has almost always greater velocity than the cold current, as has already been mentioned, and further in the fact that the warm air is lighter than the cold so that the pressure is lowered on the eastern side.

Whether the whirl movement advances at a velocity different from that of the mass, as is the case in wave movements appears not to be determined theoretically; however, according to the occasionally very great velocities of translation of cyclones it is very probably. The rapid movement of areas of pressure rise and pressure fall also argue in favor of it. The lesser velocity of anticyclones as compared with cyclones is related to the moderate value of the difference between deflecting force and centrifugal force, which are oppositely directed, while in the cyclones the sum of these codirected forces exerts a much stronger effect.

In the fixed (stationär) movement the gradient force becomes very strong in the innermost region of cyclones through the concerted action of these two forces, in the anticyclone it becomes very weak on account of the opposing functions of the two forces.

In an earlier work (*Bildung von windhosen und Zyklonen,*) Sitzungsber. d. Akad. d. Wiss., Abt. IIa, 132 Bd., 1923) I showed an experiment in which, in a rotating tub whose water was warmed at the circumference and cooled in the center, there formed cold and warm currents, from and toward the center and therewith whirls in cyclonic and anticyclonic direction.

These experiments argue in favor of the views given above, still they have not been carried out with sufficient accuracy.

When the north current undergoes a deflection toward the east, on its eastern side as a rule, and the south current also undergoes a deflection to the east, the complicated current processes arise, and then there frequently appears the tendency for one current to cut across the other, as is seen in Charts I to VI (not reproduced). In the nonparallel course of two currents it may be of importance [to note] that in convergence the velocities are increased and there occurs a pressure fall, while in divergence there is a pressure rise through lowering of wind force.

An exact investigation of these current processes is wanting, both theoretical and practical connections. Still the phenomena mentioned at the outset give the impression that *the constant variability of air movement arises from heat supply and cold supply, which produce the circulations;* in them turbulence and mixing of the masses apparently play a very complicated rôle. Phenomena that were earlier assumed to be main causes, such as precipitation and evaporation, may be of secondary importance only. Naturally the positions of continents and oceans have great influence. But from the results of this work it can not be assumed that on an entirely uniform earth surface the variabilities would fail [to appear]; *on an entirely symmetrical hemisphere numerous circulations that have no constant form are to be expected.*

In the future of meteorology the investigation of currents may, therefore, play the most important rôle.

ATLAS OF CHARTS [6]

The atlas of charts published by the Central Meteorological Service of Austria includes the charted material from which Professor Exner drew the results and conclusions set out in the immediately preceding abstract. For convenience some of the details of the chart construction are repeated.

The atlas contains 90 pairs of lithographed charts, each pair representing the pressure distribution for the Northern Hemisphere by isobars drawn for each centimeter between 72 and 79 (28.34 to 31.10 inches). The left half of the charts is used for pressure and the right half for temperature anomalies, negative areas being shaded and positive without shading. The charts are folded in the middle and when bound come within the modest compass of 13 by 10½ inches (33 by 25 cm.).

The number of observing stations, 120, even if distributed geographically to the best advantage, would be but a single station to each 820,000 square miles of the total surface area of the Northern Hemisphere. As a matter of fact, the distribution of meteorological stations is irregular, there being a closer network in Europe and North America than in Asia. For the United States there were selected but 10 stations, 2 on the Pacific coast in California, 2 along the Gulf of Mexico, 1 on the Atlantic coast, 1 on the Mexican border, and the remaining 4 were Chicago, Salt Lake City, Oklahoma, and New Orleans.

There are both advantages and disadvantages in using a small number of stations. The advantages are less labor and greater simplicity in chart construction, and the disadvantages are that the station network is of so coarse a mesh that many important details are lost. This is particularly true of temperature anomalies. A comparison of the Exner temperature anomaly charts with those for the identical period constructed twice daily in the Forecast Division of the Weather Bureau reveals the existence of a considerable number of both positive and negative temperature anomalies lying often side by side that do not appear on Professor Exner's charts. Naturally, this was to have been expected. The result is that the number of circulations as given is smaller than would have been found by the use of more complete observational material. It is also a fair inference that the broad sweep of the isobars across continents, while perfectly legitimate from the material at hand, would be materially altered with a larger number of stations. On the other hand, to have used the more complete material when and where available would have added immensely to the labor and complexity in reaching the results set forth by the author as based upon largely generalized data.

[6] Karten der Atmospharischen Zirkulation auf der Nordlichen Halbkugel Herausgegeben von der Zentralanstalt fur Meteorologie und Geodynamik.

DISCUSSION

One can not but admire the courage of Professor Exner in undertaking with the small number of meteorological stations available to discuss the elusive problem of the form, extent, and apparent movement of areas of positive and negative temperature anomaly that appear daily on weather charts for the Northern Hemisphere.

The question naturally arises, What approach to accuracy is obtained by the use of a small number of stations? The present writer undertook to compare the results for North America with the twice daily forecast charts for the corresponding period made and filed in the United States Weather Bureau Forecast Division. Naturally, because of the closer network of stations used in drawing those charts, material differences were found and some areas of positive or negative temperature anomaly came to light which the highly generalized charts of Professor Exner did not show.

In the absence of a detailed comparison of the two sets of charts it is impossible to say to what, if any, extent the general conclusions of the author might be changed.

The Weather Bureau charts present the departures from normal temperature of the current 8 a. m. and 8 p. m. temperatures (seventy-fifth meridian time). Obviously these departures would be slightly different were the daily mean temperatures considered. In any event the labor of making an accurate check of the results of the two sets of charts is prohibitive.

THE WEATHER SITUATION IN EUROPE IN THE WINTER OF 1928-29 [1]

By F. M. EXNER

In February, 1929, the cold was very abnormal over all Europe; at Vienna on the morning of the 11th there was recorded a minimum of −14.8° F., a temperature that had not occurred at that point since the establishment of the station; that is, since the year 1775. In the course of the 154 years, during which observations have been made regularly, a temperature of −4° or lower was recorded 14 times; the lowest reading previous to this year was −11.2° in January, 1850. The 14 instances of very low temperature show no regularity as to time of occurrence; no period relative to the coldest years can be determined. On the morning of February 11 the severity of the cold just above the ground was a striking feature; while the reading was −14.8° at an elevation of 2 meters, it was −25.6° a few centimeters above the surface of the snow. This lowering of temperature was caused by radiation from the snow to the clear sky. Immediately below the surface of the ground the temperature was 14°; at depths of 2 centimeters, 50 centimeters; and at 1 meter the readings were 17.6°, 28.4°, and 35.6°, respectively. In the snow and in the ground conduction of heat is rather slow, so with clear sky in winter the surface of the earth is very strongly cooled through outward radiation.

The cold of winter is, of course, mainly the result of outward radiation. Since in our winter the sun has its position south of the Equator, the duration of solar radiation and its intensity in the Northern Hemisphere are considerably less then than in summer; in the tropical region the radiation of heat from the sun is great even in winter and then exceeds the outward radiation from the earth's surface to space; that is, the tropical region has an influx of heat even in that season. The regions of our latitudes, and the polar regions especially, have, however, in winter more outward radiation than insolation and there thus results in these higher latitudes a loss in heat.

Despite this continuous loss of heat through outward radiation in winter we do not regularly have a continuous cooling, but often a stableness in temperature or even an increase therein; this is possible only through supply of heat from lower latitudes accomplished by transportation of air. Normally the western part of Europe is much warmer in winter than the eastern part; this comes about solely through the fact that in winter the transportation of air from the south takes place more actively in western Europe than it does in eastern Europe.

Hence, the main question of the causes of our phenomena of cold and heat resolves into those of the so-called circulations. In the tropical region there prevails a heat source; the air is warmed by the ground, which is heated by solar radiation. In the polar regions there prevails a cold source; the air is made cool by the ground, which is cooled by outward radiation. The result of the warming of the air in the Tropics and its cooling in high latitudes is a circulation. Aloft there is a flow of warm air toward higher latitudes and at the ground a flow of cold air toward lower latitudes.

Of course a symmetrical circulation over the whole Northern Hemisphere is precluded. The two currents can not occur in similar manner over the whole hemisphere for the reason that the rotation of the earth produces a deflecting force which causes the poleward current to undergo deviation toward the east and the equatorward current deviation toward the west. Therefore, the circulation from cold region to warm region and in the reverse direction can take place along a meridian circle only when in connection with the poleward current there lies low pressure to the west and the deflecting force of the earth's rotation is counterbalanced by the pressure gradient; in that case a current can penetrate to the Pole. On the other hand, with a current from the north, there must be present a pressure gradient toward the east in order that the cold masses may penetrate the tropical region. Thus there form between the two currents regions of high and of low pressure; for example, if a warm current flows from south to north and on its western side there flows a cold current from north to south, then between these two branches of a circulation there lies a region of low pressure, and, on the other hand, if the cold current flows on the eastern side of the warm one there lies between the two currents a region of high pressure.

Thus the cyclone and the anticyclone appear as a result of the circulation that unquestionably must result from the presence of sources of heat and cold in fluids. All air movement on the earth is made possible by heat energy. The specially intense phenomena of air movement, such as the cyclones, originate through friction between the two currents of the circulation. We may designate such cyclones friction whirls, whose axes lie not vertical but nearly horizontal. Each cyclone and each anticyclone effects, through mixing of the air, a kind of temperature adjustment with the two currents between which it lies. The main currents of the cold and of the warm air lie, however, at the sides of the true areas of the cyclones and the anticyclones and an adjustment of temperature is maintained by these two phenomena, but still not fully effected. As a result the warm air to the east of the cyclone flows still farther toward the cold region while the

[1] *Meteorologische Zeitschrift*. April, 1929.

cold air west of the cyclone moves still farther toward the warm region, the south. At length the warm air masses arriving in the polar region spread toward the right and toward the left, the current divides into two or more parts and intermingles with the cold mass of air. In the south the cold current divides toward east and west; through this division the advancing cool air is warmed more and more until at length as warm air it flows from the tropical toward the polar region. By "circulation" we are to understand continuous circulatory movement of each air mass.

The stretches over which a circulation first takes place do not generally remain continuously the same. In the winter of our latitudes the oceans are relatively warmer than the continents; therefore, a warm current holds itself rather to the ocean than to the continent. Normally, however, parts of the warm current invade the continents again and again, for the most part toward the east. In analogous manner the cold currents keep rather to the cold continents, but they, too, divide and flow out over the oceans. Hence, under normal conditions the cyclones of our hemisphere migrate toward the east or the northeast, so that in reality all regions from the subtropics to the Pole are crossed by cyclones. Usually we see on the Northern Hemisphere two or three great circulations lying adjacent to one another, and, as was mentioned above, there appear small branches on both sides of the main currents. On account of the great mobility of the air, these circulations are very variable, and at present we have no rather exact knowledge of the individual phenomena. Only after observation of the momentary forms of circulation are we able to estimate the change in the same in the immediate future.

In the winter of 1928–29 the usual circulation consisting of three to four systems at the beginning gradually transformed into only two main systems of circulation; that is, into cold currents from the north over Eurasia and North America and warm currents over the Atlantic and Pacific Oceans; this was accomplished in February. The great continental region of northern Asia and northern Europe had evidently become colder and colder on account of preceding snowfall, since the outward radiation from snow cover is very intense while insolation is strongly reflected from it and effects no particular retardation of the cooling. Through this outward radiation the air at the ground had cooled more and more. On account of its greater specific gravity, it could not be removed by winds of higher temperature; the cold air masses increased in size and, as a region of high atmospheric pressure, began to spread out on all sides. This outspreading naturally took place toward warmer regions. Thus there originated cold currents toward south, east, and west, and to greater extent over the lowlands, since on account of friction at the ground the cold air mass does not advance so rapidly as the warm air mass which extends higher. The cold currents of the circulations have, therefore, for the most part a wider extension at the earth's surface than those of the warm currents.

In its western extent the cold current from the northern part of Eurasia moved in true normal manner toward southern and western Europe. This took place in connection with two warm currents that regularly occur with cold continental air—when a warm current over the Atlantic, especially one from low latitudes, advances northward at the eastern limit of the ocean the warm air can keep to the regions of the seas, the regions north and northeast of Scandinavia, and that of the Mediterranean Sea. As a result of pressure differences aloft this form of circulation carries the warm air toward the coldest surface regions, thus from the eastern part of the Atlantic Ocean over Spitzbergen and Nova Zembla toward interior Asia and also over the Mediterranean Sea toward southern Russia. With this invasion of warm air into the cold region there form on the left of the warm currents whirl formations (cyclones), through which there results lower pressure in the region of rotation between currents, and this draws in new cold masses from the left side of the current. The invasion of a warm current to the Arctic border of Russia regularly had as a result a new invasion of cold from the north toward the southwest, whereby the warm current which had entered the northern continental region was cut off by the cold current. Likewise the bending of a warm current to the east into the Mediterranean Sea regularly brought about a rotation over the Mediterranean Sea and a new invasion of cold toward Austria, and this frequently reached as far as Italy.

At the same time there is present on the western border of the cold mass, bordering the warm Atlantic current, a regular bending of the cold current from the northeast to west, northwest, and even north; without this parallel flowing of the cold border mass and the adjacent warm winds no continuing condition will be able to exist on account of the deflecting force of the earth's rotation. In this way the current from east to west and northwest came to be continuous and brought intense cooling even to England. The warm current on the west could not dissipate the cold, since there came a continuous supply of cold air masses from the east.

Southern Russia and central Europe had throughout the entire time lower temperatures than the Lofoden Islands, Iceland, and Spitzbergen. Since the warm current over the Atlantic could not shift toward the east on account of the intense cold over Eurasia, but remained over the ocean, the related cold countercurrent on the west held continuously to the region of North America. In eastern Asia the cold current continued through the cold period in that region, so the warm current to the east was limited to the Pacific Ocean. In this way there were maintained, especially after the latter half of January, only the two above-mentioned circulations over the Northern Hemisphere.

The greater the number of circulations that are present on the hemisphere the more variable becomes the weather; the fewer the circulations the more uniform the weather.

The manner in which such phenomena began with the coming winter is not known. The air mass over the earth is continually in motion, and must have in its enormously great dimensions very complicated changes in movement that are much more difficult to understand than, for example, movements of water in rivers and seas; the atmosphere has no banks or shores; the continents and the oceans alone give us a bit of understanding. Consequently, the phenomena of currents on the whole of our globe present a difficult problem which we can grasp somewhat better only gradually through investigation of the currents. The ideas that any extraterrestrial, cosmic phenomena have an influence on such weather situations appear to me to be entirely unwarranted.—*Translated by W. W. Reed.*

NOCTURNAL TEMPERATURE INVERSIONS NEAR THE GULF COAST

By RAY A. DYKE

[Weather Bureau office, New Orleans, La.]

Temperature inversions have been studied carefully in some regions of rugged topography and well-defined air drainage, with considerable temperature differences between stations variously located. But in the more level regions there seems to be less opportunity for practical application of temperature studies of the lower air in the vertical dimension. Yet the study has promise of application that at first may not be obvious.

On the Plains near the coasts of Texas and Louisiana the conditions most favorable for nocturnal temperature inversions in winter occur in that part of areas of high pressure in which pressure gradients are slight, embracing areas of considerable extent, in which the winds may be northerly or westerly but sometimes easterly or southerly after the crest of the area of high pressure has passed. Steeper pressure gradients may prevail on the morning before the first night of an inversion, but the changes to slight gradient may usually be foreseen. In most instances the free-air velocities a few hundred feet above the ground and generally within the inversion layer are not far from the average velocities for the elevation, the interference induced by turbulence largely ceasing at sunset at such elevations, while at the ground increasing density and friction retard and almost halt air movement.

In an investigation of minimum temperature differences, in order to relate minimum temperature forecasts for the principal stations to the minimum temperatures recorded at substations, comparison has been made for some stations near the Gulf coast, showing the differences between roof and ground exposures. Among the influences that may tend to increase the amount of difference that occurs with nocturnal inversion we may mention city heat, dust, smoke, and surface differences, with concrete, stone, and brick contrasting with lawns, trees, and frame dwellings. Furthermore, the stations are some miles apart instead of one above the other. Yet we know that under favorable atmospheric conditions inversion will occur whether the city be present or not.

It should not be assumed, a priori, that all the city influences operate to increase the minimum temperatures of a station on a city roof. Roofs are good radiators, as is visibly illustrated when slate roofs are coated with frost at a height of 30 to 40 feet above the ground. There should be good insulation between a flat roof and the rooms below it, though radiation from the roof surface implies some conduction. The structures in a city increase the total radiation surface but communicate heat also. The net result of all the factors appears to be a slight increase in temperature due to city influences, but we are told that the growth of a city and a multiplication of its heat-producing power does not change its climate, a conclusion that is well supported by the evidence of comparative records (*1*) (*2*).

In order that the currents from ventilators may noticeably affect the minimum temperature readings, it is necessary not only that the wind come from certain narrowly limited directions when the temperature is lowest but also must be strong enough to turn the current against the thermometer shelter. Observations of the angle of ascending smoke at New Orleans indicate that air currents from ventilators on the post-office building are not likely to affect the temperature readings under conditions favorable for temperature inversion.

The smoke produced by orchard heaters designed for smokiness is no doubt denser than that overlying our cities near the Gulf coast, though not so extensive. Young (*3*), using a Weather Bureau pyrgeometer, found that the radiation measured under smoke produced by smoky orchard heaters during nights at Pomona, Calif., and Medford, Oreg., was reduced by about 10 per cent as compared to air where the smoke was not present. The effect on surface temperatures can only be conjectured; but if a 20° to 30° fall in temperature at night is diminished by only 2° to 3° when the smoke is very dense the lighter smoke of most cities may be expected to have less effect. Differences of 14° to 18° sometimes occur between the roof station and the nearest suburban or cooperative station, and we may safely infer that much the larger part of the difference is due to nocturnal radiation, with resulting inversion.

Differences in minimum temperatures, under given sky conditions and wind movement, have been computed for stations in New Orleans. New Orleans No. 1 is the principal station, with thermometers 11 feet above the roof of the post-office building and 76 feet above the ground. The anemometer is 84 feet above the ground.

The station known as Carrollton is within New Orleans, on the grounds of Loyola University, and faces the avenue bounding the narrow end of Audubon Park. Prior to 1926 the thermometer shelter at this station was located with the thermometers about 9 feet above sod on a rear lawn; but for the last few years the shelter has been about 50 feet above ground on a tower of one of the smaller buildings, which stands well isolated from surrounding structures, in a locality where the grass cover is extensive but not far from the paved avenue. The thermometer shelter is slightly larger and the slats thicker than Weather Bureau shelters, but admits air readily through its louvered sides.

Audubon Park station, known as New Orleans No. 2, is in the park, about 300 yards from the Mississippi River and about 1 mile from the Carrollton station, which is about 3½ miles from the New Orleans No. 1. The park is about one-half mile wide at the river end. Well built up residential sections lie on either side, with some industrial plants near to the west.

Light smoke, drifting slowly over the city, including the park, gives the latter a characteristic of city exposure, while the considerable expanse of vegetative cover gives it the character of a rural exposure. When the Audubon Park records are compared with those of other substations in southeastern Louisiana we find that with conditions favorable for radiation towns west of New Orleans along the river are in close agreement with Audubon Park, while minimum temperatures near Houma, in a rural location about 60 miles southwest of New Orleans, on clear nights of light wind movement as well as when windy conditions obtain, are usually 1° to 2° and sometimes 3° lower than the minimum temperatures at Audubon Park and have been still lower in a few instances during the onset of a cold wave. Not being near the large bodies of water that nearly surround New Orleans, Houma may be expected to have lower temperatures. The cold windy conditions also give lower temperatures along the river west of New Orleans than are recorded at Audubon Park.

The small differences between the minimum temperatures at Audubon Park and surrounding stations, when conditions are favorable for radiation, show that city smoke and dust have very little effect on temperatures 5 feet above the ground in a park in this city.

In Table 1 the New Orleans stations are arranged in the order of elevation. The record covers four years, except that a longer period was found necessary for the lower temperature, 32° or lower at New Orleans No. 1.

TABLE 1.—*Average minimum temperatures at stations in New Orleans, La.*

Sky and wind conditions	Number of instances	Average temperatures: Audubon Park, 5 feet	Carrollton, 9 feet	Carrollton, 50 feet	New Orleans No. 1, 76 feet	Differences
		°	°	°	°	°
Clear, with wind movement 7 miles per hour or less	87 81 48	43.1	46.2	47.3	51.7 51.9 49.9	8.6 5.7 2.6
Clear, with wind movement more than 7 miles per hour	48 48	43.2	36.4	....	45.7 37.8	2.5 1.4
		Average temperatures 32° or less				
Clear, with wind movement 7 miles per hour or less	10	23.8	....	....	28.7	4.9
Clear, with wind above 7 miles per hour	21	24.8	....	....	26.3	1.5
Cloudy, with moderate to strong winds	19	28.8	....	....	29.1	0.3

NOTE.—There were no instances of light winds with cloudy weather (low clouds) during the nights when minimum temperatures were 32° or lower in the period used.

It is worthy of note that for wind velocities of 7 miles an hour or less the average difference between the lowest and highest stations is 8.6° on clear nights, but for winds of more than 7 miles an hour the average is only 2.5° F. For temperatures of 32° or lower, with winds 7 miles or less the average difference is 4.9° F.

For temperatures above 32° the greatest difference was 16°, March 21, 1922, when the minimum was 57° at New Orleans No. 1 and 41° at Audubon Park. An instance of considerable difference with frost occurred on December 2, 1916, when the minimum temperature was 47° at New Orleans No. 1 and 34° at Audubon Park. For temperatures below 32° the greatest difference since 1910 occurred on January 7, 1924, with 27° at New Orleans No. 1 and 18° at Audubon Park, with average hourly wind movement of 4 miles, which is an unusually low wind movement for the temperatures. The preceding night had been very cold, and though the night of the 6th and 7th was clear there was a fall of only 6° from the maximum of the 6th at New Orleans No. 1. This matter of slight fall from maximum to minimum at the roof station is worthy of further study. Quite recently, on December 3, 1929, we forecast a minimum temperature of 26° to 32° at New Orleans. Conditions were highly favorable for radiation. The temperature at New Orleans No. 1 fell from a maximum of 41° to a minimum of 39°, while at Audubon Park the fall was from 43° to 28°. Great damage occurred with this freeze in the sugar region, where minimum temperatures of 22° to 28° occurred as forecast, with a temperature of 24° continuing for three hours in much of the sugar region.

That the inversions are less for the lower temperatures, when winds are alike, is in accordance with theory. The lower the temperature of a body the less heat it has to radiate, the rate of radiation varying directly with the fourth power of the absolute temperature of the body, according to the physicists. In addition, as the surface of the soil grows colder conduction from beneath is increased to balance the loss of heat at the surface. In other words, lowering the temperature increases the effect of the reserve supply of heat on the temperature, and this applies not only to the reserve in the soil but also to other sources of heat such as are found in a city.

Since the temperature fall at the ground is less with the lower temperature the air at a higher elevation is cooled less and the difference between the maximum and minimum at the roof station is relatively smaller than when there is greater cooling at the ground.

Referring again to Table 1, we note that the effect of increasing elevation may be seen in the reduced difference between New Orleans No. 1 and Carrollton after the thermometers were placed higher at Carrollton.

Recent records for Houston and Harrisburg, Tex., compared for temperatures of 32° or lower at Harrisburg and the minimum temperatures, with other conditions, at Houston, are averaged in Table 2. These records, while not strictly on the same basis as the comparison made at New Orleans, are available at the present writing and will serve to illustrate inversion.

Houston is on the southeastern plains of Texas, with ground elevation about 50 feet above mean Gulf level. Since November, 1926, the anemometer has been exposed 314 feet above ground on the roof of one of the tallest buildings, and the period of this study begins with this date. The thermometers are 292 feet above the ground and 10 feet above the roof.

Harrisburg, about 7 miles southeast of Houston, with ground elevation 38 feet and thermometers 5 feet above the ground on a level prairie, represents rural conditions.

TABLE 2.—*Average minimum temperatures on clear nights at Houston and Harrisburg, Tex.*

[For nights with minimum temperatures 32° or lower at Harrisburg]

	Number of instances	Harrisburg	Houston	Difference	Greatest difference	Date	Least differences	Date
		°	°	°	°		°	
Wind less than 9 miles per hour	6	27.8	43.0	15.2	17	Jan. 28, 1928	14	Dec. 21, 1928 Dec. 23, 1928
Wind 9 to 13 miles per hour	17	27.8	37.3	9.5	16	Dec. 24, 1928	1	Jan. 4, 1928
Wind 14 miles per hour or more	21	28.5	29.2	.7	16	[1] Nov. 22, 1928	−4	[2] Dec. 31, 1927
		For minimum temperatures 32° or less at Houston						
Wind 9 to 13 miles per hour	4	23.8	27.8	4.0	6	Jan. 7, 1929	1	Jan. 4, 1928
Wind 14 miles per hour or more	10	25.9	25.8	−.1	4	Feb. 11, 1929	−4	[2] Dec. 31, 1927

[1] Winds up to midnight, Nov. 21–22, 1928, 8 miles per hour. Windy therafter but inversion not overcome. Strong inversion on this date at Groesbeck, Tex., with light wind at ground and fresh to strong at 250 meters above the ground.

[2] Temperature higher at Harrisburg than at Houston, with difference of 4°. Strictly, the least difference was 0.

It will be seen that the upper group in Table 2 is inclusive of temperatures in the lower group; but no temperatures of more than 32° F. at Houston are included in the lower group. As there are not many instances of temperatures of the lower group, the results are not essentially altered by making the upper group exclusive of the lower group.

The average wind movement for clear nights in which the temperature differences between Houston and Harrisburg averaged 15.2° F. was 7 miles per hour, and for the clear nights, with average difference of 9.5°, was 11.7 miles. For winds of 14 miles or more per hour the average temperature difference was negligible.

On nights with low clouds the minimum temperatures were about the same. A moderate difference sometimes occurred with high clouds and low or moderate wind movement. If conditions are favorable for inversion, cirrus clouds have slight effect in reducing the amount of inversion.

Sometimes for the part of a night the wind velocity increased to much above the averages stated, but if there was considerable inversion there were nearly always at least a few hours in which the wind movement at the roof exposure was light. In some instances the lighter winds would occur in the first half of the night and in other instances in the second half, or they might be separated by a few hours of stronger winds. The stations are 7 miles apart, which may account for one exception, hereafter referred to.

As Young (*4*) showed by observations on a wireless tower in a valley near Medford, Oreg., it does not require an entire night to produce a large inversion of temperature. Inversions in that locality were fully reached at 11 p. m., without increase thereafter, while the temperature fell at both the stations, upper and lower.

The records of instruments carried by kites show not only the nocturnal inversions due to the cooling earth but also other inversions at higher levels which occur rather frequently because of clouds and moving air layers from different sources.

The aerological station near Groesbeck, Tex., is surrounded by a nearly level plain, with slight depressions due to small water branches. The principal nocturnal inversions over the Groesbeck station in the period November 1, 1927, to January 31, 1929, have been compiled. Most of the flights were started at or shortly before 6 a. m., ninetieth meridian time, and some at 7 to 8 a. m. For wind records we have the hourly readings of the station anemometer 55 feet above the ground. The early morning balloon flights provide an approximation of the wind velocity 820 feet above the surface. The kites are reeled off rapidly when launched, but a stop is made at 500 meters out in order that the instrument may adjust itself. Records could not be secured in several instances favoring inversion because of winds too light to secure a flight. The averages computed for this rather short record are as follows:

Average top of inversion above ground, 303 meters, or 993 feet, with individual instances ranging from 456 feet (inversion 17° F., January 27, 1928) to 1,834 feet (inversion 13.5° F., November 18, 1927). The surface temperatures in these instances were mostly near the freezing point.

Average amount of inversion, 7.1° C., or 12.8° F., with individual instances ranging from 21° F., with top of inversion 1,178 feet (November 22, 1928) to 5° F., with top also 1,178 feet (December 9, 1927).

Average wind movement, 7 p. m. to 7 a. m., 55 feet above the ground, 6 miles per hour. No large departures from the average occurred in the single hours.

Average wind movement in early morning at 250 meters, or 820 feet, above the surface, 10 meters per second, or 22 miles an hour.

The increase of wind velocity with height is characteristic. At 55 feet above the ground only one night out of 17 instances had an hour or more recorded as calm. This occurred during the night of December 2–3, 1927, with inversion of 21° F. in 719 feet, when the minimum temperature was 28° at Harrisburg and 42° at Houston. This is the exceptional instance at Houston, previously referred to, when wind at 314 feet above the ground moved 12 to 20 miles an hour through the night during a considerable inversion.

During the period studied when marked inversions were noted at Houston inversions were recorded also at Groesbeck if a kite flight was made.

As many of our principal stations have the thermometers on the roofs of buildings, much comment results when ice-covered puddles are seen in the streets, though the official record of the thermometer may be above the freezing point. When the matter is explained the question is asked: "If the daily temperature range decreases with height, why does not the Weather Bureau secure its official readings nearer the ground at all stations?" There are good reasons for roof exposure of the thermometers at most of our principal stations. Even where near-by open squares or lawns are available, and they are not in many instances, we can not place guards over the instrument shelters to prevent vandalism and theft which would all too frequently cause loss of records as well as of instruments exposed near the ground in cities.

It is believed that the method of grouping data used in this paper will be found profitable in the study of minimum temperatures elsewhere. The groups of temperature selected should be subgrouped according to wind movement during the night. The limits of this paper will not permit a consideration of dew point, relative humidity, and maximum temperature as observed in the evening of the preceding day, but related data should be included. Instances of snow cover, well-frozen ground, the kind and amount of clouds, and the character of frost, if any, should be included while obtaining the other data.

Averages of minimum temperatures under all conditions are insufficient for some purposes. Some grouping of similar conditions is necessary if we are to have the knowledge that will be most effective in advising the public what temperatures to expect in order that crops may be saved, plumbing and radiators protected, concrete work suspended when necessary, shipments handled without damage, and other activities delayed when advisable or successfully pursued.

REFERENCES

(*1*) MINDLING, GEORGE W.
Influence of Artificial Heating on the Climate of Cities. MONTHLY WEATHER REVIEW, August, 1911, vol. 39, pp. 1280–1283.

(*2*) PALMER, ANDREW H.
Is the Heat Generated by Great Cities Changing Their Climates? MONTHLY WEATHER REVIEW, August, 1911, vol. 39, pp. 1284–1286.

(*3*) KIMBALL, HERBERT H., and YOUNG, FLOYD D.
Smudging as a Protection from Frost. MONTHLY WEATHER REVIEW, August, 1920, vol. 48, pp. 461–462.

(*4*) YOUNG, FLOYD D.
Nocturnal Temperature Inversions in Oregon and California. MONTHLY WEATHER REVIEW, March, 1921, vol. 49, pp. 138–148.

WEATHER PROBLEMS PECULIAR TO THE NEW YORK-CHICAGO AIRWAY

By WESLEY L. SMITH, SUPERINTENDENT, EASTERN DIVISION

[National Air Transport (Inc.), Cleveland, Ohio]

The mechanical difficulties in connection with the regular scheduled operation of airplanes in air transport service may now be said to be practically eliminated. This leaves the weather as almost exclusively the cause for our failure to operate on schedule whenever we do fail. The weather interrupts our schedules in several ways, which may be enumerated as follows:

1. By cutting down the visibility so that our planes may not land and take off safely at airports. The landing speeds of nearly all commercial airplanes are in the neighborhood of 60 miles per hour, so that visibility is a very necessary thing whenever it is necessary to make contact with the ground.

2. By coating our planes with ice, as mentioned in another paper, which is apt to set up terrific vibration on the struts and wires of the plane and may even cause structural failure in itself which would end the flight, or by overloading the plane with ice and at the same time decreasing its forward speed by increasing its head resistance, so that the plane will actually fall out of the air if the pilot has not been wise enough to land before this moment arrives.

3. By giving us head winds that subtract from the speed of the plane to such an extent that it no longer has an advantage over other means of transportation in the matter of speed.

4. By carrying us off of our courses with cross winds flying through the clouds where nothing is visible.

All of us who have any faith in the future believe that we shall conquer all of these obstacles so that eventually airplanes may be flown on regular schedules. In the meantime, in order to adhere to schedules as closely as it is possible, there are certain things that must be done. The following weather service must be provided and is being provided by the combined efforts of the United States Weather Bureau and the Airways Division of the Department of Commerce:

1. Weather reports are furnished every hour from selected points along the airway. These points in the flat country are usually airway intermediate fields about 60 miles apart. In the mountainous country these weather reports must come from the highest points as well as from some of the low points, since the airplane must fly at sufficient height to clear the highest mountains. These reports are:

(A) General weather conditions.

(B) Ceiling or height of the base of the clouds, if there are any at that particular point, measured in hundreds of feet.

(C) Visibility along the ground expressed in miles.

(D) Wind direction and velocity on the ground.

(E) Ground temperature.

(F) A barometer reading corrected to sea level.

(G) Any unusual field conditions, if the report comes from an intermediate field, such as depth of any snow that might be on the ground, soft condition of the field, if there is such, and any failure of the lighting equipment that may have occurred.

2. A short summary of the weather conditions as they are along the route and a forecast of the probable weather conditions for the next three hours is provided by a trained meteorologist of the Weather Bureau. He should be and is familiar enough with the problems of flying so that he can advise whether flights should be attempted during that period, the probabilities as to ice conditions, the height of the clouds on their topside, the probable changes in wind direction and velocity that will be encountered aloft, and changes in temperature that may be expected. In order to do all of this, a weather map for that particular area is drawn every three hours from information furnished by regular Weather Bureau stations within the area. This information should include dew points for the forecasting of possible fog and possible ice conditions.

3. After the plane is in flight the weather reports along the airway are furnished to the pilot every hour by radio so that he may be kept advised of any changing conditions. Our altimeters all measure altitude by measuring changes in air pressure, so that if the pilot is flying through or above the clouds he needs to have the barometer readings furnished to him regularly so that he may correct his altimeter for any fall or rise of the barometer that may have occurred while the plane is in flight. If fog or other weather conditions reduce the visibility at his destination so that it is not safe to attempt a landing there, weather reports are obtained from alternate airports in that vicinity and furnished to the pilot, so that he may either land at one of these alternate airports, if this is possible, or return to some point where a safe landing is possible.

The New York to Chicago airway commencing at New York starts with an elevation of almost sea level and progresses over large valleys, divided by fairly steep hills and mountain ridges to Bellefonte, Pa. These hills gradually increase in height from 500 feet in the vicinity of New York until it is necessary to fly at 3,000 feet above sea level in order to clear the mountains safely just before reaching Bellefonte. At Bellefonte the terrain rises very rapidly to a high plateau whose surface is very rough and rolling and is marked by relatively low broad mountain ridges and deep narrow river valleys. This plateau tapers off gradually to the flat Ohio Valley west of the Alleghany River. The elevations are such that it is necessary to climb rapidly to the 3,000-foot level on leaving Bellefonte in order to clear the highest points in safety and to maintain this altitude for 60 miles. The plane may then be brought safely down to the 2,500-foot level until the Alleghany River is reached, at which point an elevation of 2,000 feet becomes safe. It is necessary to maintain this elevation until within sight of Cleveland. The elevation of the intermediate field at Bellefonte is 1,000 feet and that of the Cleveland airport is 800 feet. From Cleveland to Chicago the country is fairly flat and level, with a stretch of 60 miles of rolling high country between Bryan, Ohio, and Goshen, Ind. The airway borders on the southern tip of Lake Erie from Cleveland to Toledo and crosses the southern tip of Lake Michigan just before reaching Chicago.

As a general rule the New York to Chicago airway is affected by all of the storms experienced in the United States as they move toward the St. Lawrence Valley, whence they all leave this continent. The paths of these storms may be roughly classified as follows:

(A) The most frequent ones are those that sweep along the Canadian border to the north of us from west to east.

(B) The storms which move southeastward from the Canadian northwest and then turn northeastward somewhere in the Mississippi Valley.

(C) Storms that originate on the Mexican border or beyond and move northeastward across our path.

(D) Storms that originate on the South Atlantic coast or in the West Indies and follow the Atlantic coast northeastward to Newfoundland.

In addition to the cyclonic storms mentioned, ground fogs are one of the chief causes of our irregularity of operations. The pure ground fog, which has a clear sky above it, is usually a local condition and usually causes only a few hours' delay or the use of an airport not located in the fog area.

The weather conditions that affect flying vary with the seasons of the year, so that we will discuss these by seasons, taking the summer season first. During the summer season ground fogs are very prevalent along the Atlantic seacoast and in the river valleys through the mountains. From Cleveland westward to Chicago ground fogs are encountered a great deal less frequently. Whenever the dew point hovers within 5° of the temperature at any terminal station the pilot is on the alert inasmuch as he gets this information by radio every hour. Ground fogs are more prevalent during the early morning hours and usually disappear as the sun climbs above the horizon. By providing our planes with fuel sufficient for at least five hours of flying and by the use of the radiobeacon and the weather broadcasting, it is many times possible for our planes to hover over their destination, flying in large circles awaiting the dissipation of the ground fog, when this has been forecast, and landing as soon as the fog lifts sufficiently to permit this. Before the advent of radio and this specialized weather service it was necessary for our planes to wait at the last clear point until the fog had lifted before starting for the terminal. Since ground fogs are very prevalent around New York City, it may safely be said that many hours of delay have been eliminated by this service in delivering the night mail to that city. Safe landings on large airports, such as the Cleveland airport, may be made at night through fog that is not more than 500 feet thick by the aid of the boundary light and red fuses strung across the field. Such landings are possible at night when they are not possible in the daytime because the lights will show vertically upward through the fog. In order to make such a landing, the pilot needs to have the very latest barometer reading so that he may correct his altimeter accordingly, and this can only be furnished by radio. The location of the field itself is determined by the radiobeacon located at one corner of the field.

Local thunderstorms of moderate intensity are encountered during the summer months between New York and Cleveland. These storms, with slightly increased intensity, are also encountered between Cleveland and Chicago, but the tornado of the southwest and midwest is very rare indeed. The thunderstorms that we encounter present a hazard which is mostly mental. There is probably no authentic case on record where an airplane has been struck by lightning while in flight, and our more experienced pilots do not even take the trouble to fly around these that are of small area. Here, again, the hourly weather reports keep the pilot advised as to their frequency and area. The two greatest hazards in connection with a thunderstorm are its vertical turbulance, which may dash to the ground any airplane that attempts to fly through one too close to the ground, and the brilliancy of the lightning at night, which may blind the pilot so that he will temporarily lose control of the airplane because he can not read his flight instruments. To correct these two possibilities, the experienced pilot will probably fly at least 1,000 feet above the highest points on the ground in going through a thunderstorm, and our planes are equipped with very brilliant instrument lights for such occasions. These bright lights are dimmed by a rheostat for ordinary flying conditions at night. In flying through a thunderstorm the pilot must, of course, switch off his radio set so that he will not be deafened by the sharp static crashes caused by the lightning.

In the ordinary summer storm the bottom layers of the clouds are usually within 200 or 300 feet of the ground in the flat country, and they envelop all of the higher ground, the hills, and the mountain tops, so that a flight between New York and Cleveland under such conditions must be made nonstop, since it will be dangerous to attempt to land at any intermediate point if the storm covers all of this area. If the flight be a westbound flight it will be made at an elevation of about 3,000 feet to clear all of the mountain tops safely, to avoid the loss of airplane speed that would result from flying at any higher altitude, and to have as little of our prevailing west winds as it is possible to have. If the flight be an eastbound flight it would usually be made by climing through the clouds to their topside, since it is easier to fly above the clouds than it is to fly through them, and because favorable winds may be expected aloft to more than compensate for the loss in airplane speed caused by the altitude. These altitudes for the topside of the clouds will vary between 5,000 and 15,000 feet, depending upon the general conditions. For all such flights the pilot needs to have weather reports broadcast hourly so that he may be kept advised of any changing conditions on the ground. He needs to have barometer readings so that he may keep his altimeter correctly set, and he needs to have weather reports from alternate airports near his destination should the weather become unsafe for landing at his destination. Before the flight is started he needs to be assured by the meteorologist that weather conditions will not change for the worst at his destination and to be furnished with the probable direction and velocity of the winds at various altitudes. Until quite recently this latter information concerning the winds aloft was an unknown quantity, since the meteorologist had no means of measuring these in a storm. But the pilots' reports and the speeds actually made by our airplanes under such conditions, coupled with the weather maps, have given us all an insight into what we may expect. The radiobeacon provides a sure path for the plane through the clouds under such conditions and the radio marker beacons keep the pilot advised as to his progress along the airway.

The advent of winter brings us the ice problem, which is probably our greatest one. When freezing temperatures prevail the process of flying through the clouds is an impossibility, and since the storms with their attending low clouds are more frequent in the winter time than at any other time our flying is greatly curtailed during the winter months. Such information as dew points, ground temperatures, and ground elevations become very necessary for any flying that may be attempted during this period, as explained in another paper. Snow itself is not the hazard to flying that it is generally considered to be. The dry snowflakes of the real low-temperature snowstorm do nothing more serious than to cut the visibility down to a very low point. The clouds in such a snowstorm are usually higher above the ground than are those in a rainstorm, so that it is possible to fly through this sort of a snowstorm and see straight down even though there is no visibility ahead. Under such conditions it is almost impossible to measure in any way from the ground the ceiling or height of the clouds, since a balloon or the ray of the ceiling light is quickly swallowed up by the

snowflakes themselves. In the mountainous country the clouds usually envelop only the highest points, so that it may be possible to fly below the clouds until these points are reached and then through them over the high points themselves. Under such conditions the ice that accumulates on the plane while flying through the clouds for 5 or 10 minutes is usually not enough to cause any serious trouble with the plane from vibration or extra weight.

However, the snow that we get in the wake of each storm caused by cold northwest winds blowing across Lakes Michigan and Erie, which are relatively warmer, and then over colder land again are a very different thing. This sort of snow is apt to be a very wet snow, and as a result very apt to cling to the airplane in the form of ice. A wet moist fog generally accompanies such snow and causes a further precipitation of ice upon the plane. This sort of snow is prevalent on the south and east shores of Lakes Michigan and Erie and is apt to carry eastward from Lake Erie to the Appalachian Mountains. It disappears almost entirely east of Bellefonte.

A flight under similar conditions between Cleveland and Chicago may sometimes be made by flying beneath the clouds all of the way, but it is usually necessary to fly through the clouds over the high point on the Ohio-Indiana State line.

The clouds in a storm usually have a tendency to remain above flat territory but to arch down to meet and envelop any high points along the way. A plane flying from New York to Cleveland at an elevation of 3,000 feet may, and frequently does, find itself beneath the clouds over the valleys but very much in the clouds when flying over the ridges and high points even though the elevation of the plane has not been changed. Under such conditions the clouds themselves are seldom cut off sharply on their lower side, and there are occasional breaks in their lower layers so that it is many times possible to fly through these lower layers at a safe elevation and to catch an occasional sight of the ground for location.

The clouds themselves frequently exist in solid layers so that the pilot may find himself flying between layers for extended periods. If this be over mountainous country these layers usually meet over the high points and separate again when the next valley is reached. It is the ultimate plan to place radio marker beacons on the strategic high points so that the pilot flying under such conditions may know when he has passed any one of these. For any flying done under such conditions the pilot must, of course, have a very definite knowledge of the ground elevations below him so that he may always fly at a safe elevation. When the destination is reached and the ceiling is reported as very low, the usual procedure is to come down to an elevation of about 500 feet above the actual reported ceiling and to fly along at this elevation until a hole appears in the clouds where a quick descent is made until plane is beneath the bottom layers.

Pilots need to be kept advised by the meteorologist of the location of the line-squall or wind-shift, line if there is such, since this line is usually an area of great turbulance and possible thunderheads. Having been advised of the location and probable movement of the line squall before the flight is started, the pilot can then check its progress with reference to his flight by the hourly weather reports.

With the approach of autumn come shorter days, larger and more frequent storms, lower temperatures, and more fog in connection with the storms. The pilot needs to be a little more careful in pushing through the storms because of the greater possibility of the fog beneath them, particularly when on-shore winds of low velocity prevail at New York, Cleveland, or Chicago. The ice condition begins to appear at the higher altitudes, so that flying through storms begins to be a process of flying through the clouds rather than over them on eastbound trips. It is not possible to safely come down out of the clouds where low ceilings prevail at night, unless this is done over a lighted area, and if this lighted area be a city there are many tall buildings that makes this process very dangerous, so that the shorter days curtail a great deal the bad-weather flying that can otherwise be safely done.

With the approach of a storn from the Mexican border during the winter months the temperature usually rises above the freezing point. Unless the southwest winds be very strong under such conditions, fog is apt to envelop the whole area, particularly so if there be a great deal of moisture on the ground in the shape of snow. As the storm passes to the north the temperature will drop at the wind-shift line, and while flight may be possible in the southwest corner of this storm the freezing zone will be encountered again as the wind-shift line passes, and our pilots have to be very careful of the ice danger in flying through this wind-shift zone and into the snow flurries that usually come from the lakes in the wake of the storm.

Sleet and freezing rain are other winter possibilities which are encountered occasionally. In a freezing rainstorm the ice usually forms upon the plane and weights it down to the ground within five minutes, so that no attempt is usually made to fly under such conditions. In a sleet storm the ice does not form on the plane so fast and it may be possible to climb quickly to the warmer temperatures above that usually exist in these cases and thereby get out of the ice danger. Under such conditions of inversion it is sometimes possible to get above the clouds on eastbound trips, and even though the temperature be below the freezing point at that altitude any accumulation of ice will usually disappear by evaporation. It is sometimes found under such conditions that the inversion only extends to a certain altitude and that the normal temperature lapse rate with altitude then occurs. Under such conditions the pilot must stay in that zone where the temperature is above the freezing point, and this will usually be somewhere in the midst of the clouds.

We are equipping our planes as fast as it is possible with hygrometers and air thermometers so that the pilot may avoid the ice condition, when it is possible, by choosing an elevation which will give him a temperature and a humidity where the ice hazard is not present. The air thermometer serves as an ice-wanring indicator also because when ice forms on its exposed heat-measuring element the temperature recorded in the cockpit will be that of the freezing point. Any departure from this temperature either up or down will immediately indicate to the pilot that ice has ceased to form upon the plane.

The advent of spring brings us warmer temperatures over moisture-soaked ground, so that general fog conditions are apt to prevail during the spring months. The temperature will usually cross the freezing zone each time a storm approaches and recedes, so that actual ground visibilities are apt to be less at these times than at any other. The ice hazard is greatest at temperatures near the freezing point and is therefore at its worst in the springtime. The fact that the emergency fields are very apt to be too soft for safe landings due to the thawing conditions makes attempts to fly when weather conditions are doubtful during the spring months very hazardous to airplanes.

Because ice seems to be the greatest hazard to aviation, the Daniel Guggenheim Foundation for the Promotion of Aviation has endowed a research laboratory in the physics department of Cornell University. A test wind tunnel in a chamber has been installed and the ice conditions have been duplicated in the laboratory. Close cooperation and exchange of information between the Airways Weather Bureau stations of the New York-Chicago Airway, the experimental laboratory and the National Air Transport (Inc.) have made this possible. Attempts of various kinds to solve the ice problem and remove the hazard are being made in the laboratory, and those that appear to have possibilities will be given further tests upon our planes this winter. All of us who are cooperating in the effort believe that the solution of the problem will be found at sometime in the near future.

EXPOSURE OF RAIN GAGES

By B. R. LASKOWSKI

[Read before the American Meteorological Society meeting at Des Moines, Iowa, December 27-28, 1929]

One of the main problems confronting a Weather Bureau man in establishing a new station is proper exposure for the rain gage.

It should be remembered that the standard rain gages located at the various 4,000 Weather Bureau stations in the United States furnish the only available precipitation records procurable for consultation, and for that reason they should be as nearly comparable as possible.

Prominent meteorologists, who have given this subject much thought and experiment, admit that when there is no wind large and small drops of rain, fine particles of mist, and even light snowflakes will settle down vertically to the ground, and the records of all gages within a mile or two will correspond quite closely when considered over a long period of time if there are no topographic effects to be considered. If there is a wind blowing the larger drops, falling swiftly, go into the gage without much effort, while the lighter ones are apt to be carried off to one side. Snowflakes have been known to enter a gage and then be whirled out again, making the catch decidedly deficient. This deficiency has been variously estimated from almost nothing to over 10 per cent.

Being interested in the subject and wishing to know first-hand what this difference in catch would be in Kansas, I procured a standard 8-inch gage over five years ago and set it up on a grass plot at my residence on Shawnee Avenue, Topeka, Kans., a distance of about 17 city blocks from the Weather Bureau office. The gage is well protected by trees and buildings, so that there is not apt to be any interference due to direct winds immediately at the gage. All the objects are at least as far away from the gage as their height above it. The ground between the Shawnee Avenue gage and the Weather Bureau is but slightly rolling, so there are no topographic effects worth mentioning. Whereas the Shawnee Avenue gage is located on the ground, the Weather Bureau gage is located on a flat roof of a 6-story building which is considerably higher than surrounding buildings. This roof is somewhat protected by a 5-foot parapet at the edge of the building, but the wind has a much better sweep over that gage than the one located on the ground.

Daily observations of the catch of the two gages for the 5-year period ending September 30, 1929, are offered herewith for comparison's sake. The graphs for the individual months invariably show greater catches for the ground gage. This was especially noted when the wind was gusty or squally, while at periods when the wind movement was very light or nearly calm the two gages would average about the same. In fact, the daily record shows many instances when they correspond exactly. It will be observed by the graphs that the greater differences always occurred during the summer months, when the precipitation mostly occurs during thundershowers, at which time the winds are apt to be quite high and of a shifting nature. In winter, when the precipitation is in the form of snow, as a rule, the monthly totals agree closely, and there is even then a slight advantage in favor of the ground-exposed gage. From a negligible difference in January the differences increase gradually until about the 1st of April, when the thundershower period commences, after which the increase is decided and continues so until the closing days of September, and then recedes to conditions similar to those found at the first of the year. In other words, the greatest difference in catch is during the growing season of the year. That being the case, it was decided to also compare these particular differences for the two seasons of the year, the winter and growing season.

The first charts exhibited indicate the monthly catches and we find the following:

Taking the full year's record into account and commencing with the first entry, October, 1924, the first year the catch in the ground gage was 28.47 inches and the roof gage 25.93 inches; the second year the ground gage totaled 32.47 inches and the roof gage 29.46 inches; the third year, 49.78 inches to 46.54 inches; the fourth year, 30.15 inches to 27.96 inches; and the fifth year, 38.63 inches to 34.71 inches. In other words, the annual catch in the ground-exposed gage exceeded the roof gage the first year 2.54 inches; the second year, 3.01 inches; the third year, 3.24 inches; the fourth year, 2.19 inches; and the fifth year, 3.92 inches. The average annual difference in catch for the five years was 2.98 inches. Expressed in percentages, the ground-exposed gage exceeded the roof gage the first year by 10 per cent; the second year, 10 per cent; the third year, 7 per cent; the fourth year, 8 per cent; and the fifth year, 11 per cent. The average for the 5-year period is 9 per cent.

In consulting all the charts—monthly, annual, and average—for five years for the two seasons mentioned in the fore part of this paper, the winter season, and the growing season, we have the following: During the winter season, October to March, inclusive, the ground-exposed gage collected the first season 6.04 inches, while the roof gage collected 5.68 inches; the second season the totals were 10.66 to 9.16 inches; the third season, 14.43 to 14.09 inches; the fourth season, 6.92 to 7.53 inches; and the fifth season, 15.85 to 14.48 inches. The differences this time, by seasons, amounted to 0.36 inch, 1.50 inches, 0.34 inch, −0.61 inch, and 1.37 inches. This, given in percentages, was 6, 16, 2, −8, and 9, or an average for the entire period of 6 per cent.

Taking the growing season, April to September, for study, the ground-exposed gage showed a total of 22.43 inches the first season, as compared to 20.25 inches on the roof; the second season, 21.81 to 20.30 inches; the third season, 35.35 to 32.45 inches; the fourth season, 23.23 to 20.43 inches; and the fifth season, 22.78 to 20.23 inches. The differences here are for the first season, 2.18 inches; the second, 1.51 inches; the third, 2.90 inches; the fourth,

2.80 inches; and the fifth, 2.55 inches. The average for the entire period totaled 2.39 inches. Converting these differences to percentages again, we have the following: 11, 7, 9, 14, and 12, and the average for the period 11 per cent.

A difference of 10 per cent in the actual amount of rainfall would be a very important matter in the semiarid sections of the West.

Since the following study corroborates what others have found out in the past as regards the difference in catch between ground-exposed and elevated gages, it must be admitted that the Weather Bureau is doing the proper thing by insisting that rain gages should be located on the ground whenever it is at all possible, so that uniform records may be obtained.

Monthly catch of precipitation

GROUND-EXPOSED GAGE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1924	------	------	------	------	------	------	------	------	------	0.60	1.04	1.95
1925	0.44	0.62	1.39	4.67	1.87	6.86	3.45	1.08	4.50	4.20	1.19	0.28
1926	1.15	1.74	2.10	2.79	3.37	2.55	2.53	3.64	6.93	6.04	1.40	0.87
1927	0.75	0.63	4.74	6.41	2.83	8.62	7.00	7.08	3.41	2.62	0.73	0.67
1928	0.03	2.30	0.57	2.67	2.84	5.77	3.55	6.13	2.27	1.68	6.97	1.35
1929	2.51	1.32	2.02	5.24	6.49	4.34	1.91	2.69	2.11	------	------	------
Means	0.98	1.32	2.16	4.36	3.48	5.63	3.69	4.12	3.84	3.03	2.27	1.02

ROOF-EXPOSED GAGE

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1924	------	------	------	------	------	------	------	------	------	0.66	0.88	2.16
1925	0.28	0.55	1.15	4.40	1.92	6.05	3.44	0.87	3.57	3.28	1.12	0.19
1926	1.12	1.39	2.06	2.71	3.01	2.49	2.42	3.27	6.40	4.90	1.42	0.97
1927	0.73	0.76	5.31	5.10	2.69	8.19	6.23	6.80	3.44	3.05	0.72	0.78
1928	0.02	2.43	0.53	2.69	2.46	5.11	2.75	4.91	2.51	1.47	6.08	1.24
1929	2.42	1.26	2.01	5.26	5.96	3.18	1.70	2.64	1.49	------	------	------
Means	0.91	1.28	2.21	4.03	3.21	5.00	3.31	3.70	3.48	2.67	2.04	1.07

Annual catch of precipitation

[Year, October to September, inclusive]

YEAR	Ground-exposed gage	Roof-exposed gage	Difference in catch	Difference in catch
	Inches	*Inches*	*Inches*	*Per cent*
First	28.47	25.93	2.54	10
Second	32.47	29.46	3.01	10
Third	49.78	46.54	3.24	7
Fourth	30.15	27.96	2.19	8
Fifth	38.63	34.71	3.92	11
Means	35.90	32.92	2.98	9

CATCH DURING THE WINTER SEASON

[Season, October to March, inclusive]

SEASON				
First	6.04	5.68	0.36	6
Second	10.66	9.16	1.50	16
Third	14.43	14.09	0.34	2
Fourth	6.92	7.53	−0.61	−8
Fifth	15.85	14.48	1.37	9
Means	10.78	10.19	0.59	6

CATCH DURING GROWING SEASON

[Season, April to September, inclusive]

SEASON				
First	22.43	20.25	2.18	11
Second	21.81	20.30	1.51	7
Third	35.35	32.45	2.90	9
Fourth	23.23	20.43	2.80	14
Fifth	22.78	20.23	2.55	12
Means	25.12	22.73	2.39	11

A FACTOR IN THE TEMPERATURE OF THE STRATOSPHERE

By W. J. HUMPHREYS

When we first heard, some 30 years ago, that the temperature of the air rather rapidly decreases with increase of height up to the level of the highest currus, or wispy, clouds, and from there on as far as a balloon could carry a thermometer remains practically constant, we just didn't believe it—not all of it. We accepted, of course, the first part of the statement to the effect that the greater the height the colder the air. We had gotten used to that from mountain climbing and from the records kept by balloonists. Then, too, we had found a good physical reason why it should be so, or at any rate an essential part of that reason. It is this: Ascending air expands, because the pressure on it grows less and less by the weight of the air left below, but it expands against the weight of the air that still is above it, and therefore does work. Now, to do work it must expend energy, and its available energy for this purpose is its heat. Evidently then, ascending air, expanding as it goes, and doing work at the expense of its own heat, must get colder and colder with increase of height. All this is in perfect accord with our laboratory experiments, and so we accepted the fact of the decrease of temperature with increase of height as a phenomenon which, if not entirely selfevident, at least is so easy to explain as scarcely to merit a passing thought.

That is where we made at least two mistakes. In the first place, even when it does occur it isn't half so easy to explain as we thought it was, and, in the second place, it doesn't occur at all in the high atmosphere. Of course the pressure continuously decreases with gain of level beyond the highest clouds, just as it does below them, and so asking us to believe that the temperature does not also decrease up there with increase of level just as it does in the cloud region was asking too much; it was contrary to our laboratory experience. However, after hundreds of records obtained by sounding balloons (small balloons carrying only registering instruments) had shown that immediately the uppermost cloud level is passed the temperature really is practically constant, why of course we had to accept it as a fact, and revise our explanations accordingly.

In the end it all came out simply enough. Our previous reasoning had been perfectly correct, but the premises were sadly deficient. We had left out of account the effects of radiation, and had set no limit to convection. Throughout all that portion of the atmosphere in which clouds of any kind occur, that is, from the surface up to the height of 6 to 7 miles, in middle latitutes, and 8 to 10 miles in tropical regions, there is decided convection—change in level of individual masses of air. The temperature, therefore, of each such mass does vary with height, and as the whole of this portion of the atmosphere is involved in this continuous vertical turnover so also does this temperature relation extend to its every portion. But beyond the clouds vertical convection, if it exists at all, is so slow as to be practically absent so far as temperature effects are concerned. Here no one portion of the air changes temperature with altitude for the good and sufficient reason that it neither rises nor falls. Heat is not added to it by compression, nor taken from it by

expansion. It therefore comes to that particular temperature at which it can lose heat by radiation at exactly the same rate that it gains heat by absorption. From this level up the intensity of the radiation from the earth and atmosphere below is practically independent of height. That is why temperature up there also is independent of height. It doesn't change appreciably even from day to night, and so we infer that it is not much affected by sunshine directly.

Thus again we had come to that state of mental ease that goeth with understanding. But the ease was of short duration. It soon was found that the upper air, the stratosphere, as scientists now call it, is coldest over equatorial regions and becomes gradually warmer with increase of latitude, the extreme difference being around 35° F.—coldest over the warmest earth and warmest over the coldest earth. Here was a poser, and we are not through trying to explain it yet. And now they (certain scientists) tell us that up beyond the highest reach of our balloons there is ozone in the very thin air. Well, that is what we would expect from the fact that ozone is produced whenever a certain portion of ultra-violet radiation falls on oxygen. But botheration again! There seems to be least ozone over tropical regions, where we would expect most, and more and more with increase of distance from the equator, and not less and less. Well, this isn't explained yet either, but we can make use of it, and that is what we propose now to do.

Ozone is a powerful absorber of the long wave-length radiation that goes out from the earth and its water-soaked atmosphere. Furthermore, whatever quantity of radiation the ozone absorbs, that same quantity, changed in part to other wave lengths, it must reradiate, otherwise it clearly would do what obviously it is not doing, that is, continuously get either warmer or colder. Now, as the radiation by the ozone evidently is as much in one direction as another, half of it is back towards the lower atmosphere. It also is evident that where there is least ozone the percentage of absorption and reradiation also is least, and as the quantity of the ozone increases so also does this percentage of return radiation. In short, one reason (not the only one) why the stratosphere becomes colder and colder as we go from high latitudes to the Equator, is because the ozone blanket at the same time grows thinner. It is a little like sleeping warmly outdoors under a quilt or shivering under a sheet—lots depends on the kind and quantity of covering one has.

ICE STORM OF DECEMBER 17–18, 1929, AT BUFFALO, N. Y.

By J. H. SPENCER, Weather Bureau

On the morning weather map of December 17, 1929, pressure was high along the Canadian border and to the northward, while a moderate LOW extended from the southern part of the upper Lake region southwestwardly to Oklahoma and northern Texas. Light north to east winds resulted in the Lake region. The striking feature on the weather map of this date was the fact that moderate to heavy rains were falling over the southern half of the Lake region, with temperature below the freezing point at the surface. The temperature at 8 a. m. at Buffalo, for instance, was 26°, rain falling at the time. Rain continued throughout the day and most of the night, exceeding an inch.

Part of the heavy rain at Buffalo froze as it fell, or soon after, making streets and sidewalks very slippery and dangerous, but sloppy above the ice in many sections. Practically all the time that rain fell the temperature was below freezing. The resulting ice storm of Tuesday and Tuesday night, December 17, was one of the worst of record here. Hundreds of street trees were severely damaged. The weight of the ice Tuesday night was at least double that which resulted from the ice storm of December 7 and 8. Tree branches the size of an ordinary lead pencil were enlarged by the ice to the thickness of 1 to $1\frac{1}{2}$ inches. Thousands of limbs as large as one's arm were broken off by the weight of the ice, great damage resulting.

ICE ON BRANCHES

Forsythia branch.—Length, 1 yard 4 inches. No lateral twigs. Total weight, with ice, $1\frac{1}{8}$ pounds; without ice, $\frac{5}{8}$ ounce. Greatest diameter of ice, $1\frac{1}{4}$ inch to full $1\frac{1}{2}$ inch. Slightly uneven, due to buds at 2 to 3 inch intervals. Top diameter of ice was 1 inch and narrowing to a knife blade at bottom. (See fig. 1.)

Thickness of ice above wood, about $\frac{7}{8}$ inch; below wood, $\frac{1}{4}$ to $\frac{3}{8}$ inch. Weight of wood, $\frac{5}{8}$ ounce. Diameter of wood alone, $\frac{1}{8}$ inch at small end and $\frac{1}{4}$ inch at large end. Ice coating was as thick at one end as at the other.

Elm branches.—From one large limb lying on the street I broke off four tips, each about 15 inches long, and with lateral twigs, without disturbing the ice. Collectively they weighed, with ice, $2\frac{1}{2}$ pounds; without ice, 3 ounces.

One ornamental tree in my yard, as large as a full-grown fruit tree, was completely broken down. I broke off a tip 28 inches long, with lateral twigs, from one branch; weight, with ice, $1\frac{1}{2}$ pounds; without ice, 1 ounce. It was impossible to see between the icy branches of this tree; that is, one could not see the street or any object on the other side of the tree, so heavy was the ice on the limbs.

FIGURE 1

After these measurements were made, I brought the ice-covered branches into a warm room, with temperature of 70°, and it took more than two hours for the ice to melt away sufficiently for it to break away from the wood. This illustrates roughly how difficult it is in a cold climate to get rid of the ice before it does great damage merely by remaining on objects for many hours and often days after the ice storm occurs.

AFTER THE ICE STORM

Cold weather, with temperature below freezing, and without sunshine, continued through December 18, 19, and 20. Ice remained as heavy on trees and wires as on the night of the 17th and 18th. On the 19th there was more than an inch of sleet (very small ice pellets that looked, in the aggregate, like snow, but of great weight). Following this, a 50-mile gale blew most of the time for 24 hours, beginning soon after 8 a. m. of the 20th; and on the night of the 20th and 21st there was a 6-inch fall of snow, which drifted badly. These long-continued severe conditions caused great damage and much hardship in the Buffalo district and throughout western New York.

To combat the situation many hundreds of linesmen were brought in from distant cities to repair the damage on telephone and telegraph lines; traction companies operated with difficulty; some bus lines were unable to operate at all; electric light service was interrupted, failing entirely in many sections; hundreds of automobiles were stalled along the highways; railroad trains ran hours late; all the principal radio stations were unable to operate; large numbers of aerials were down; "Christmas shopping" was interfered with; and numerous injuries and several deaths were attributed to the storms. Rarely indeed has this section been visited by such a procession of severe storms.

Most of the great damage to trees occurred on the night of the 17th and 18th, during a comparative calm; while the greater part of the damage to telephone and telegraph lines followed that date, particularly during the gale on the day of the 20th and night of the 20th and 21st. Damage from all these conditions will be between one and a half to two millions or more; but no one will know for several weeks to come. I think the above is a conservative estimate.

OUTSTANDING FEATURES

Almost incredible quantities of ice accumulated on trees, shrubbery, and other objects. (See special reference thereto.) The streets and boulevards of Buffalo were so badly cluttered up with broken-off branches after the storm that an appropriation of $50,000 was asked for to clean up the city. It will cost I believe, several times that amount to replace trees and trim up those that can be saved. I have seen in other parts of the country damage to telephone and telegraph lines quite as severe as occurred here, but never anything like the damage to trees. All night long of the 17th and 18th one was kept awake by the breaking limbs, which snapped off with a report much louder than a rifle shot. It was a depressing and never-to-be-forgotten experience. Otherwise the night was quiet, there being very little wind.

In 35 years' experience I have never seen Weather Bureau instruments so completely frozen up. The vane and anemometer were heavily caked with ice and put out of commission both at the downtown office and the airport. There was a mass of ice more than 2 inches thick on one side of the sunshine recorder.

The losses mount up, as the work of restoration progresses. I think this is approximately correct:

Total losses in western New York, including the Buffalo and Rochester districts, were around $3,000,000, perhaps more. More than 8,000 telephone poles were carried down by the sleet and wind, with approximately 15,000 miles of wire. The telephone companies alone sustained a loss of approximately $2,000,000.

HAILSTORMS OF 1929 IN THE UNITED STATES

By S. D. FLORA

[Weather Bureau office, Topeka, Kans.]

[Condensed from a report by the author]

Hail damage was severe and widespread during 1929 but not as bad as in 1928, which was one of the worst, if not the worst, hail years in the history of the country. While the total loss by hail for 1929, like that of previous years, will probably never be known definitely, the United States Weather Bureau received reports of more than 225 severe hailstorms during the year with property losses exceeding $10,000,000. The total losses will greatly exceed these estimates from outstanding storms as there were hundreds, possibly thousands, of falls of light or moderate hail, most of them doing but little damage for which no statistics are available.

One of the best indexes of hail damage over the country is the Iowa record, which is compiled from reports collected by the assessors, making that State the only one, so far as known, that knows the amount of its hail loss. This is given in the following table:

Hail damage in Iowa

1923	$2, 319, 506
1924	6, 703, 838
1925	7, 975, 691
1926	2, 342, 187
1927	5, 064, 717
1928	6, 363, 922
1929	[1] 2, 354, 551

[1] The 1929 figures are estimated from losses paid by insurance companies in Iowa, which were 37 per cent of the losses of the previous year.

There are probably several mid-western States that, if complete records were available, would show as great or even greater loss than Iowa. In Kansas hail losses actually paid by insurance companies in recent years have averaged close to two-thirds the Iowa totals, which include uninsured as well as insured crops, and it is known that a very large per cent of hail losses in Kansas are not covered by insurance. In 1929 hail losses of outstanding storms in Kansas, as reported to the Weather Bureau, totalled $2,403,500, with hundreds of smaller losses not reported.

Hail is always a special menace in Kansas on account of the immense wheat crop of the State, which approaches maturity during the season when hailstorms are most likely to occur. In the western third of the State Weather Bureau records indicate that heavy hail falls three to four times a year somewhere in each 10,000 square miles of area.

Thirty-eight heavy falls of hail were reported in Kansas last year and 15 of these occurred in June, with the wheat crop almost ready for harvest. Even so, the State was more fortunate than in 1928, when it suffered losses of a million dollars or more from each of six hailstorms. Ten of the 1929 Kansas hailstorms caused losses of $100,000 or greater each and one that extended from Byers to near Sawyer, diagonally across Pratt County, on June 13, resulted in a half-million-dollar loss. The path was 1 to 4 miles wide and 30 miles long. Wheat in the area was damaged 20 to 50 per cent.

Two days previous to the Pratt County storm hail fell over a path 60 miles long in Rawlins, Decatur, and Norton Counties, in northwestern Kansas, and almost totally destroyed wheat in some places. The worst of this storm was felt at New Alemelo, Norton County. The total damage was placed at $300,000.

Another of the Kansas hailstorms moved from near Newton to Cassoday, Butler County, on June 12, with the heaviest damage near DeGraff, Cassoday, McLain, and Potwin. The total loss was valued at $150,000. Along the path of severest hail wheat was a complete loss and the oats destroyed in some places. The grain was hammered into the ground until in some fields not a stem was left standing. Chickens, ducks, and geese, as well as birds, pigeons, and jack rabbits, perished literally by the hundreds.

It remained for an eastern State to report the greatest damage from a single hailstorm in 1929. This was a million-dollar loss at and near Hartford, Conn., on August 1, and the greater part of the damage was to greenhouses and the tobacco crop.

A hailstorm in Illinois on May 1 that extended from Cora to Raleigh caused a loss of $720,000. The hail was so severe that roofs were pierced, windows broken greenhouses practically demolished, and fruit ruined over a path 2 to 6 miles wide and 6 miles long. * * *

PRELIMINARY STATEMENT OF TORNADOES IN THE UNITED STATES DURING 1929

By HERBERT C. HUNTER

[Weather Bureau, Washington, January 30, 1930]

In advance of the final study of the 1929 windstorms which is expected to be finished during the coming summer, the following preliminary statement, compiled from the material thus far available from section directors and others, is presented:

TORNADOES AND PROBABLE TORNADOES

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Number	5	5	17	60	37	11	6	4	7	2	0	4	158
Deaths	9	23	20	168	35	2	0	0	0	1	----	0	258
Damage [1]	10	160	352	4,824	1,408	733	32	151	2	4	----	6	7,682

TORNADIC WINDS AND POSSIBLE TORNADOES [2]

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Number	1	0	4	5	3	2	2	0	0	3	0	0	20
Deaths	4	----	0	0	3	0	0	----	----	0	----	----	7
Damage [1]	1,250	----	20	20	50	2	(3)	----	----	5	----	----	1,347

[1] In thousands of dollars. [2] Several of these, in the final study, will probably be classed as not tornadoes. [3] No estimate of the damage was obtained for either.

CYCLE RECURRENCES WITH VARIABLE LENGTH OF BOTH PERIOD AND AMPLITUDE [1]

By CHARLES F. MARVIN

[Weather Bureau, Washington, January 18, 1930]

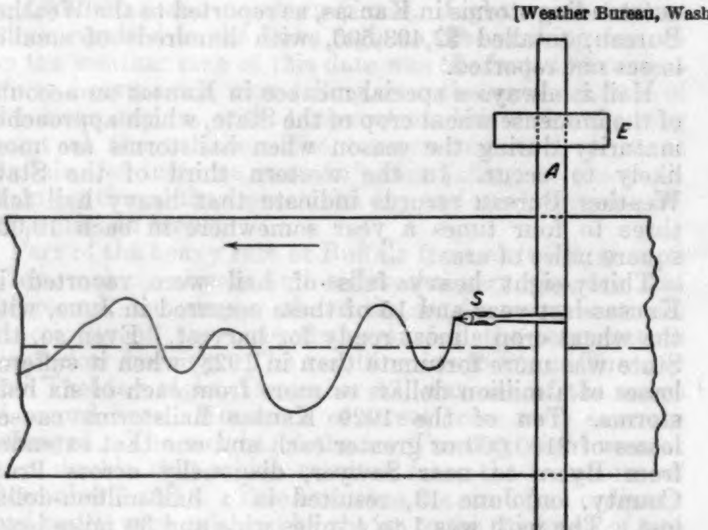


FIGURE 1.—Harmonic analyzer

Following a bit further our interesting discussions of yesterday, concerning cycles and periodicities, I think I would like to state in writing briefly what I tried to make clear in our conversation regarding my conception of the geometrical background or basis for cycle recurrences with variable lengths of both period and amplitude. These conceptions have been in my mind for a great many years, in fact ever since our associate, Mr. Clough, began to advocate his theory of handling periodicities with various lengths and amplitudes.

I think that what I have to say can be made most clear by aid of the accompanying diagram (fig. 1), in which D is a disk revolving about its center, with a movable crank pin, P, which can be either fixed in any desirable position in the slot across the top of the disk, or it can have independent movement to or fro in the slot, either from the center outward in one direction, or from one side of the disk to the opposite, etc. The plate AA is carried between lateral guides, C_1C_2 to the guide at E. This plate carries a stylus, S, for tracing movements of the plate. The crank pin, P, engages a slotted opening in the plate A, and, when the disk D is rotated, gives lineal harmonic motion to the plate A and the stylus S. If, now, a band of paper is moved continuously forward under the stylus S, a record is traced of the combined movements of the paper and of the stylus. When the crank pin retains a fixed position and D is revolved at a uniform rate we have uniform motion of a point in the circle which traces out the conventional trigonometric curve on the paper. It is obvious, however, that if the rotation of the disk D is not uniform but executed in an accelerated and decelerated manner the period of the harmonic curve traced out will be variable and not constant. It is equally obvious that if

[1] This paper was prepared in the form of a letter to Dr. A. E. Douglass, University of Tucson, Tucson, Ariz.

the rotation of D is made constant and the movement of the paper is made variable, the same result will be secured. Finally, if the crank pin itself independently changes its radial distance from the axis of D, the amplitude of the curve will be modified, and if in this motion of the crank pin, P, it passes across the center of the revolving disk, D, the effect on the trace is as if the phase of the harmonic trace had changed 180°.

The equation proposed by Fujiwhara[2] is

$$x = A(t) \sin \frac{2n}{P(t)} (t + e(t)).$$

This, so far as I know, is the first effort any of the mathematicians have made to analyze the problem of periodicities with variable length and amplitude. As soon as this paper came to my attention, my mechanical device for tracing variable periodicities led me to point out the fact that Fujiwhara's equation has a redundancy of variables, especially if he makes the phase variable. To do the latter in my mechanical model means that the crank pin, P, must have not only radial motion but also circumferential motion, and we then at once have any particular position of the stylus, S, defined by two or more possibilities, namely, acceleration or deceleration of the disk, coupled with either change of radius or change in the circumferential position of the crank pin. This concept of variable phase angle impresses me as an undesirable redundancy in Fujiwhara's equation, and I would replace that term by a constant phase angle.

[2] Jour. Faculty of Sci. Imp. Univ. of Tokyo. Sec. 1, vol. 1, pt. 10, p. 392.

I have already mentioned that variation in the length of the period can be secured either by accelerating and retarding the forward motion of the paper on which the record is traced, or retaining uniform forward motion for the paper variable lengths of period result from acceleration and retardation of rotation of D. We are, therefore, at liberty to choose either one of these.

Finally, I mentioned that if the radial motion of the crank pin carries it across the center of D it has the effect of sudden change of phase of 180°. I therefore imagine our conception of these periodic curves in nature is best represented by radial motion of the crank pin only from the center outward, although some writers seem to claim they constantly find the phase of their cycle curves change 180°. If this is actually the case in nature it is represented in the mechanical model in the way I have indicated.

You can see, of course, that with only one disk and one slide "A," any curve can be represented by movements of the crank pin in and out from the center, combined with variable paper on disk speeds. This is a vastly simpler concept of periodic motions in nature than to suppose such natural periodicities are made up of a multitude of harmonic elements. However, I think we should not require one mechanical model of this kind to represent all the details of a complex periodic curve, but rather the problem is to find a comparatively few elements having individual and separate variable amplitudes and periods of their own, which in combination produce the complex curve nature gives us.

THE WEATHER OF 1929 IN THE UNITED STATES

By ALFRED J. HENRY

Temperature, Chart 1.—Area alone considered, the year must be ranked as a moderately cool one, largely due to low temperatures in parts of the country in January, February, April, May, and September; in both Atlantic and Pacific coast States, however, mean temperature was above normal and there was also a small area of above-normal temperature in the Southwest as shown by the chart. The departures from normal rarely equaled or exceeded 2° F. (See Table 1.).

Precipitation, Chart 2.—The outstanding feature in the distribution of precipitation was the severe drought in Pacific coast and Plateau States, which happily ended in December in that region, southern California alone excepted, and it has since ended there.

The South Atlantic States and both Alabama and Tennessee experienced the second year of excessive precipitation, Tennessee excepted. The heavy precipitation in the South Atlantic and East Gulf States was due in great measure to the occurrence of two tropical cyclones within a short space of time. (See Table 2.) Following is quoted from Weekly Weather and Crop Bulletin of January 14, 1930:

> During the growing season there were two outstanding adverse conditions with regard to rainfall. Too much moisture was harmful in the early spring in most central valley sections and greatly delayed the planting of corn; later in the season, especially during the latter part of July and in August, many sections had damaging drought. The latter was most severe between the Mississippi River and Rocky Mountains, but was generally widespread in character, and, as a result spring planted crops were rather widely damaged. * * *

TABLE 1.—*Monthly and annual temperature departures, 1929*

District	January	February	March	April	May	June	July	August	September	October	November	December	Average
New England	+0.5	+1.7	+4.8	+0.4	+1.3	+1.1	−0.4	−1.5	+1.6	−1.1	+1.5	−0.6	+0.8
Middle Atlantic	+1.2	+0.1	+6.7	+3.1	−0.5	+0.1	−0.6	−1.7	+1.4	−2.0	+1.4	+1.4	+0.9
South Atlantic	+3.0	−1.0	+4.8	+3.3	−0.4	−1.3	−1.2	−0.1	−0.2	−1.4	+1.8	+0.2	+0.6
Florida Peninsula	+3.3	+3.9	+3.2	+3.2	+1.6	−0.3	−1.1	+0.2	+0.6	−2.0	+3.5	+0.1	+1.4
East Gulf	+2.8	−2.8	+3.9	+3.5	0.0	−0.9	−0.8	+0.7	−0.4	−1.4	−0.4	−1.5	+0.2
West Gulf	+1.0	−7.4	+3.0	+3.7	−1.2	0.0	−0.6	+1.8	+0.9	+1.2	−6.0	+0.6	−0.2
Ohio Valley and Tennessee	−1.0	−5.0	+5.9	+3.3	−2.2	−1.6	−0.5	−2.2	−0.1	−2.0	−2.1	+0.6	−0.6
Lower Lakes	−1.3	−1.8	+7.9	+2.9	−1.9	−1.4	−0.1	−2.6	+1.2	−1.9	−1.2	−1.5	−0.1
Upper Lakes	−6.2	−4.1	+6.0	+2.4	−2.2	−2.4	+0.6	−1.0	−0.3	−0.8	−3.0	−1.4	−1.0
North Dakota	−9.3	−4.6	+8.2	+0.8	−4.6	−0.9	+2.6	+3.2	−4.5	+3.2	−1.6	−1.2	−0.7
Upper Mississippi Valley	−7.8	−6.7	+5.8	+2.3	−3.1	−2.2	+0.4	−0.7	−1.5	−0.2	−4.0	+0.6	−1.4
Missouri Valley	−7.2	−7.1	+5.8	+2.2	−2.2	−1.3	+1.5	+2.3	−2.7	+1.2	−4.5	+1.7	−0.9
Northern Slope	−8.5	−8.0	+3.7	−1.7	−1.8	−0.5	+3.0	+5.0	−4.4	+2.5	−3.7	+2.3	−1.0
Middle Slope	−3.1	−8.0	+2.9	+1.8	−2.3	+0.5	+1.0	+2.4	−1.8	+0.6	−7.2	+3.2	−0.8
Southern Slope	+0.7	−6.6	+1.0	+3.1	−2.3	+1.5	−0.4	+2.7	+0.2	+1.3	−7.0	+1.6	−0.4
Southern Plateau	−0.2	−3.5	−0.4	−0.5	+1.2	+1.4	+1.4	+1.2	+1.5	+2.5	−1.4	+4.2	+0.6
Middle Plateau	−2.5	−6.3	−0.4	−3.7	+1.4	−0.1	+2.7	+3.1	−1.0	+2.6	−1.9	+7.0	+0.1
Northern Plateau	−8.6	−10.7	+0.8	−3.4	+0.5	−0.6	+1.7	+4.9	−2.2	+2.7	−3.4	+5.6	−1.1
North Pacific	−4.3	−4.0	+0.4	−2.8	+0.2	+0.2	+0.9	+1.5	+1.8	+3.6	−0.8	+2.5	−0.1
Middle Pacific	−3.1	−1.4	0.0	−2.6	+0.5	+1.5	+1.1	+1.5	+0.5	+2.2	+1.2	+3.4	+0.4
South Pacific	−0.8	−1.6	−0.3	−2.0	+2.3	+0.8	+0.9	+3.1	+1.1	+4.0	+3.4	+4.9	+1.3
United States	−2.4	−4.0	+3.5	+0.9	−0.7	−0.3	+0.6	+1.1	−0.4	+0.7	−1.7	+1.6	[1] −0.1

[1] Annual departure.

TABLE 2.—*Precipitation departures, monthly and annual, 1929*

District	January	February	March	April	May	June	July	August	September	October	November	December	Year
New England	−0.2	+0.3	0.0	+2.3	+0.6	−0.8	−1.9	−0.8	−0.6	−0.7	−0.4	+0.4	−1.8
Middle Atlantic	−0.7	+0.6	−0.6	+2.0	+0.3	+0.4	−2.4	−1.9	+0.8	+2.1	+0.2	−0.7	+0.1
South Atlantic	+0.1	+2.5	+0.9	+0.1	+1.7	−0.2	+0.2	−1.2	+3.7	+2.1	+0.5	+0.3	+10.7
Florida Peninsula	−0.9	−0.8	+0.9	0.0	+1.5	−0.8	+2.2	0.0	+4.8	+3.9	−1.2	+3.6	+13.2
East Gulf	+0.8	+2.3	+5.8	+0.6	+1.3	+1.2	−0.8	−1.3	+2.8	+0.7	+4.5	−2.0	+15.9
West Gulf	+0.4	−0.9	+0.1	0.0	+4.9	−1.4	0.0	−2.1	−1.0	−0.5	+1.0	−0.4	+0.1
Ohio Valley and Tennessee	+0.3	−0.4	−0.3	+0.8	+3.1	+0.1	+0.4	−1.4	+0.6	+1.3	+1.1	−0.5	+5.1
Lower Lakes	+1.0	−0.8	+0.3	+3.0	+0.6	−0.8	+0.3	−1.1	−0.4	+0.7	+0.1	+0.8	+3.7
Upper Lakes	+1.5	−1.0	+0.3	+1.7	−0.3	−0.2	−0.8	−1.4	−0.9	+0.4	−0.9	−0.2	−1.8
North Dakota	+0.3	−0.2	+0.3	+0.2	−0.4	−2.0	−0.9	−1.3	0.0	+1.0	−0.1	+0.2	−2.9
Upper Mississippi Valley	+1.4	−0.3	+0.6	+1.1	−0.4	−0.3	+0.6	−1.1	−0.5	+0.4	−0.8	−0.7	0.0
Missouri Valley	+0.7	0.0	0.0	+1.4	+1.0	+0.1	−0.9	−1.4	−0.8	+2.2	−0.4	−0.7	+1.2
Northern Slope	0.0	0.0	+0.4	+0.8	−0.5	−0.8	−0.4	0.0	+0.3	0.0	+0.1	+0.3	+0.2
Middle Slope	+0.3	−0.1	+0.2	+0.6	+0.5	0.0	+0.5	−0.9	−0.2	+0.7	+0.4	−0.5	+1.5
Southern Slope	−0.4	−0.1	+0.6	−1.2	+0.8	−1.2	−0.3	−0.9	−0.4	+0.2	−0.4	−0.3	−3.6
Southern Plateau	−0.4	−0.2	−0.3	−0.3	+1.1	−0.2	+0.1	+0.5	+0.6	0.0	−0.2	−0.6	+0.1
Middle Plateau	−0.1	−0.2	−0.1	+0.4	−0.8	−0.1	+0.3	+0.1	+0.4	−0.5	−0.6	−0.4	−1.6
Northern Plateau	+0.3	−1.0	−0.4	+0.1	−1.0	+0.3	−0.5	−0.2	−0.4	−0.7	−1.4	+0.1	−4.8
North Pacific	−3.5	−4.0	−0.5	+0.2	−0.9	+0.5	−0.2	−0.3	−2.0	−1.8	−4.9	−0.2	−17.6
Middle Pacific	−2.8	−2.2	−1.9	−0.6	−0.9	+1.1	0.0	0.0	−0.6	−1.2	−2.8	−0.2	−12.1
South Pacific	−1.2	−0.9	−0.3	+0.1	−0.4	+0.1	0.0	0.0	+0.1	−0.6	−1.0	−1.8	−5.9
United States	−0.1	−0.4	+0.3	+0.6	+0.6	−0.2	−0.2	−0.8	+0.3	+0.5	−0.3	−0.2	+0.1

NOTES, ABSTRACTS, AND REVIEWS

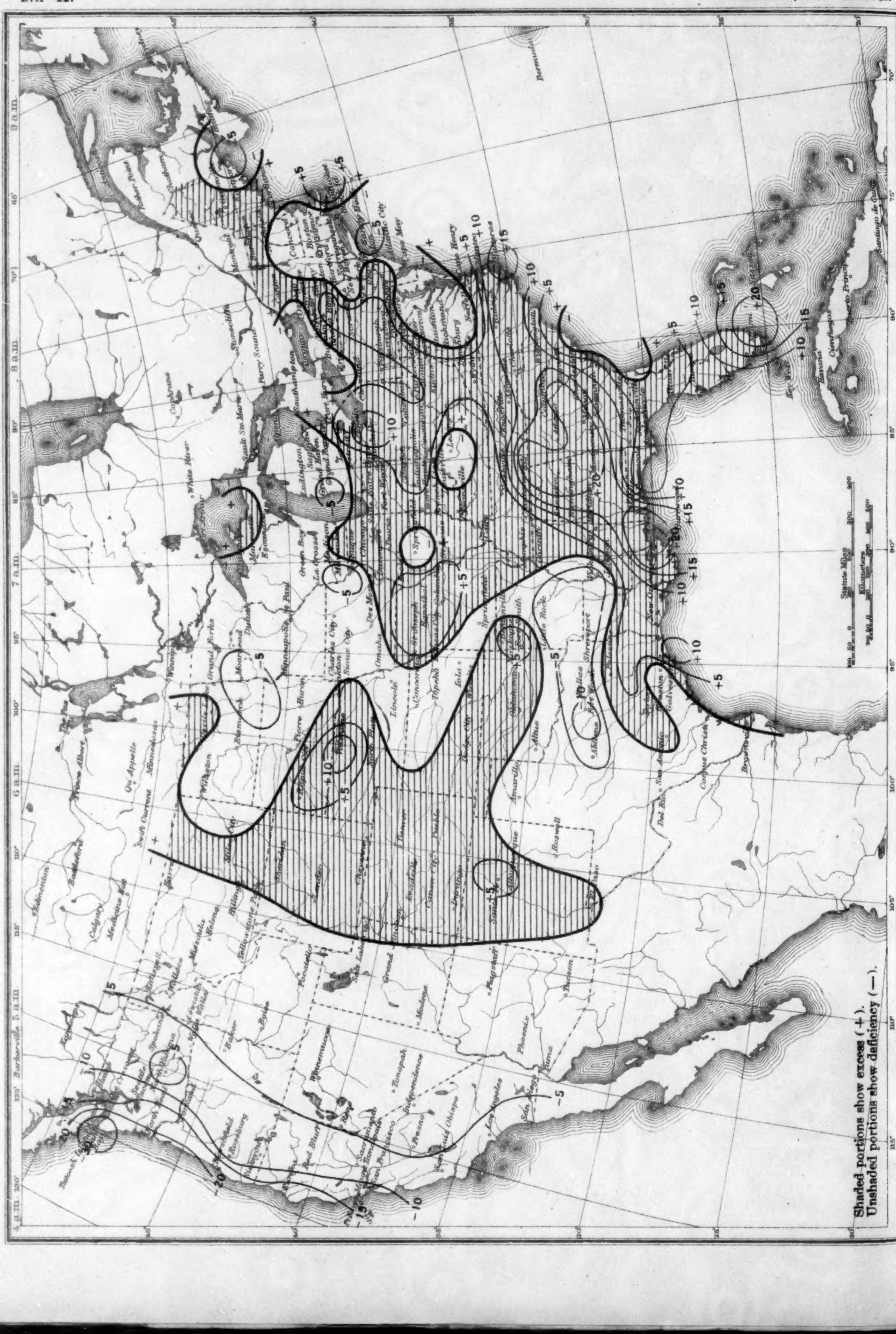
Aspects of surfaces of discontinuity (by C. K. M. Douglas (Roy. Meteorolog. Soc., J. 55, pp. 123–147; Disc., 147–151, April, 1929)).—Among the chief points discussed are: (1) Factors tending to produce sharp fronts at the earth's surface. (2) Examples of sounding of upper air temperature through rainy fronts. It is found that the surface of discontinuity is normally smoothed through a layer about a kilometer thick, inversions being rare, especially in deep depressions. It is thought that some rain belts, with associated fronts resembling "occlusions," are developed in polar air, and are not strictly "occlusions" at all. (3) Warm sectors are not surface phenomena, but are of fundamental importance in determining the upper air conditions over depressions. The fall of pressure in the warm sector in a deepening depression must be due to the spreading over of air from higher latitudes in the upper part of the troposphere and in the stratosphere. The corresponding feature of a developing anticyclone is a spreading over of tropical air at high levels. (4) Subsidence is discussed quantitatively. The development of inversions with dry air above them (comprising a very large percentage of all inversions in the troposphere above 500 meters) is considered to be due to subsidence combined with turbulence up to a definite limit. Cloud particles and precipitation are important in preventing dynamical warming at a fixed level by subsidence. (5) Sixteen striking wind discontinuities observed by pilot balloons in the British Isles in the last nine years are given, with remarks on their relation with fronts and surfaces of subsidence. (6) Turbulence at sloping surfaces of discontinuity is discussed on the basis of a criterion due to L. F. Richardson. (7) The overrunning of warm air by cold air is referred to, and it is thought that except near the ground this takes the form of continuous rather than of discontinuous motion. It is shown that a vertical front of any appreciable magnitude must be very much

A. J. H. I. Annual Temperature Departures (°F.) in the United States, 1929

(To face p. 512)

Shaded portions show excess (+).
Unshaded portions show deficiency (—).

A. J. H. II. Annual Precipitation Departures (inches) in the United States, 1929



Shaded portions show excess (+).
Unshaded portions show deficiency (−).

smoothed out. An appendix is added dealing with the combination of rotary and translatory motions. The general line of argument is that the more important pressure changes are due mainly to large-scale horizontal movements at high levels, considered in conjunction with movements at lower levels. When depressions grow deeper the resulting convergence in the lower levels influences the subsequent behavior of already existing fronts, and in certain cases forms new fronts. When anticyclones develop, the subsidence causes inversions to form which are entirely different from frontal surfaces, and in addition the divergence may sharpen up fronts at the boundaries of the anticyclones. In the discussion, J. S. Dines referred to the view held a long time back by W. H. Dines, that the cause of a depression was to be found at the base of the stratosphere.—R. S. READ. (Reprinted from Science Abstracts, No. 3279.)

The lowest temperature on the Earth[1] (*by E. Rubinstein (abstract translated by A. I. Krynitsky, United States Bureau of Standards)*).—All the data show that the lowest temperature on the globe (excluding upper layers of the atmosphere) is in the city of Verkhoyansk. The figures given by various authors are somewhat different. They fluctuate between −69.8° C. and −72° C.

It should be pointed out that in some cases the alcohol thermometers were not calibrated. This discrepancy in figures was a cause of an inquiry from the observatory of the Washington Weather Bureau in October, 1915.

Director of our observatory, B. B. Galitzin, pointed out the causes of this discrepancy and gave the temperature minimum −68° C. (round figure).

Galitzin's letter was published in full in the MONTHLY WEATHER REVIEW in August, 1917, volume 45, page 407 (B. Galitzin, "Lowest Air Temperature at a Meteorological Station"). The observations in Verkhoyansk from 1884 to 1892, inclusive, were made using the alcohol thermometer which was not checked at the low temperatures. It was found, however, that the alcohol thermometers differed from the mercury thermometers only in decimal points.

The author believes that the most reliable absolute minimum of temperature observed on the earth is −67.8° C. (−90.0° F.).

NOTE.—In contrast to the above it is interesting to note that the highest temperature ever reported, with standard thermometers and instrument shelter, 134° F. (−56.7° C.), occurred July 10, 1913, at Greenland Ranch, Death Valley, California, 178 feet below sea level.—EDITOR.

Great daily range of temperature near Rialto, Calif. (*by Albert W. Cook, Redlands, Calif*).—The greatest range in temperature ever recorded at any of the twenty-odd orchard stations of the Redlands fruit-frost district occurred on November 18–19, 1929, at Rialto, a subdivision of the district. The fruit-frost records extend from November 1 to March 1 and cover the past eight seasons. Shortly after 2 p. m. on November 18 a maximum temperature of 91° F. was recorded and by 6 o'clock the next morning the temperature had fallen 60° and frost occurred. The minimum was 30.8° F. These temperatures were recorded in a fruit-region instrument shelter located in a mature orange grove, clean cultivated, and over sandy soil.

A range of 60° is in itself remarkable, but when it is considered that the temperature drop from "summer heat" to a frost it becomes even more striking. There was, however, no deposit of white frost because of the extreme dryness of the air.

There had been no appreciable amounts of rain for several months and the soil was a dry powder. Atmospheric moisture was low for some time preceding the day in question. These conditions, coupled with almost a calm night, were conducive to a large range in temperature. The range was 50° or more for three days before the extreme range was recorded.

Monthly Weather Review Supplement No. 33, The Climate of Mexico (*by John L. Page, University of Illinois*).—Doctor Page presents a much condensed account of the climate of Mexico prepared from all of the data now available, most of which he personally compiled when on a two months' visit to the Federal Weather Service of Mexico. The publication contains no tables of climatic data; reliance is placed wholly upon a very complete series of charts and graphs. It is the most complete presentation of the subject in the English language. The supplement can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the nominal price of 15 cents the copy.—*A. J. H.*

Meteorological summary for Chile, November, 1929 (*by J. Bustos Navarrete, Observatorio del Salto, Santiago Chile*).—Atmospheric circulation had but little activity in the month of November. The most important periods of unsettled weather came near the middle of the month when three depressions crossed the extreme southern region. These depressions were charted during the periods 9th–10th, 11th–12th, and 13th–14th; all brought unsettled weather and rain over the entire southern zone.

The anticyclones of major importance were mapped in three periods—1st–8th, 17th–20th, and 23d–26th; the centers followed parabolic paths beginning near the Juan Fernandez Islands, recurving near Chiloe, and moving toward Argentina.

In the central zone the warmest weather occurred in the latter half of the month; readings above 86° F. were reported between Santiago and Chillan.—*Translated by W. W. R.*

Revista de meteorológia y aerologia. Tacubaya, D. F., Mexico.—On the editorial page of the first issue (December, 1929) the program of this publication is announced as follows:

To set forth our criterion relative to the method of studying the principal problems of our (Mexican) territory, especially those relating to the forecasting of the weather, and to suggest the most adaptable form of statistical data to promote the related discussion.

To publish the writings of the best-known foreign meteorologists on the general problems of meteorology, especially those that have great similarity to problems affecting our country.

To disseminate those interested in the compilation of meteorological data and to the public that is interested in forecasts of the weather by the *Servicio Meteorológico Mexicano*, elementary scientific instruction and internationally established terms used in the science to the end that there may accrue greater profit and better interpretation relative to such information.

—*W. W. Reed.*

[1] (In Russian) Bull. de l'Observatoire Géophysique Central, No. 1, Leningrad, 1927.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, in Charge of Library

(NOTE.—The above section will be resumed in the next issue of the REVIEW.—EDITOR.)

SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING DECEMBER, 1929

By HERBERT H. KIMBALL, Solar Radiation Investigations

For reference to descriptions of instruments and exposures and an account of the method of obtaining and reducing the measurements the reader is referred to this volume of the REVIEW, page 26.

Table 1 shows no important departures from normal solar radiation intensities for December.

Table 2 shows a deficiency in the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky at Washington, Madison, and Lincoln, and an excess at Chicago and New York, as compared with the normal amount received at the respective stations in December.

For the year these stations have recorded the percentage departures from their respective average yearly totals given in the last line of the table.

No skylight-polarization measurements were obtained at Madison during the month. At Washington measurements obtained on three days give a mean of 52 per cent and a maximum of 64 per cent on the 21st. The maximum value is an average maximum for December at Washington, but the mean is considerably below the December normal.

TABLE 1.—*Solar radiation intensities during December, 1929*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 3	2.49	0.61	0.75	0.98	0.98	------	------	0.83	0.63	------	2.87
Dec. 4	1.52	------	------	------	1.18	------	------	1.04	0.88	0.77	1.88
Dec. 20	1.78	0.84	0.95	1.14	1.32	------	------	1.01	------	------	1.45
Dec. 21	1.52	0.95	1.04	1.16	1.32	------	------	1.10	0.92	------	1.32
Dec. 31	4.37	0.85	0.94	1.03	------	------	------	------	------	------	4.57
Means	------	0.81	0.92	1.08	1.20	------	------	1.00	0.81	(0.77)	------
Departures	------	+0.03	+0.03	+0.04	−0.03	------	------	−0.03	−0.10	−0.02	------

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during December, 1929*—Con.

Madison, Wis.

Date	Sun's zenith distance										
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 4	1.32	------	------	1.10	------	------	------	1.03	------	------	1.88
Dec. 5	3.15	------	------	1.02	------	------	------	1.13	------	------	3.81
Dec. 30	3.15	------	------	------	------	------	------	1.20	------	------	4.37
Means	------	------	------	(1.06)	------	------	------	1.12	------	------	------
Departures	------	------	------	−0.15	------	------	------	+0.13	------	------	------

Lincoln, Nebr.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
Dec. 2	1.02	0.97	1.09	1.22	1.43	1.68	------	1.22	1.12	1.02	1.19
Dec. 4	3.30	0.83	0.92	1.11	------	------	------	1.13	1.01	------	4.17
Dec. 19	0.64	0.97	1.11	1.25	------	------	------	1.18	1.07	0.96	0.86
Dec. 23	1.45	------	0.83	1.02	------	------	------	------	------	------	2.62
Dec. 25	2.62	------	------	------	------	------	------	------	1.01	0.91	3.81
Dec. 27	3.81	1.02	1.10	1.21	------	------	------	1.16	1.02	------	4.17
Dec. 28	3.30	1.01	1.11	1.23	------	------	------	1.25	1.11	1.02	2.87
Dec. 30	3.00	0.94	0.95	1.23	------	------	------	1.26	1.11	1.04	3.45
Means	------	0.96	1.02	1.18	(1.43)	------	------	1.20	1.06	0.99	------
Departures	------	+0.01	-0.04	−0.04	+0.05	------	------	+0.01	−0.01	+0.03	------

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning	Average daily radiation								Average daily departure from normal				
	Washington	Madison	Lincoln	Chicago	New York	Twin Falls	Fresno	La Jolla	Washington	Madison	Lincoln	Chicago	New York
1929	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Dec. 3	195	105	154	103	170	[1] 132	192	211	+47	−18	−18	+31	+69
Dec. 10	99	33	56	27	89	78	179	208	−38	−80	−102	−41	−7
Dec. 17	119	118	196	80	97	134	130	244	−22	−6	+24	+8	−2
Dec. 24 [2]	126	106	194	117	115	203	107	227	−16	−22	+14	+38	+11
Excess or deficiency at end of year									+5,773	−1,562	−4,948	+248	−5,988
Percentage departures from average totals for the year									+4.7	−1.3	−3.6	+0.3	−6.3

[1] 4-day mean. [2] 8-day period.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Mount Wilson, and Perkins Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for fore-shortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic: Diff. long.	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day
1929	h. m.	°	°	°			
Dec. 1. (Naval Observatory).	10 34	−70.5	110.9	−13.5		154	
		−27.5	153.9	+6.5		62	
		−17.5	163.9	+17.5		278	
		0.0	181.4	+15.5		988	
		+1.5	182.9	+5.0		15	
		+17.0	198.4	+16.5	710		
		+24.5	205.9	+10.5		278	
		+35.0	216.4	−21.5		201	
		+49.5	230.9	+12.0		370	
		+59.5	240.9	+9.5		12	3,068
Dec. 2 (Yerkes)	12 40	−56.9	110.1	−13.0		180	
		−11.0	156.0	+6.8	52		
		−4.0	163.0	+17.1		250	
		+0.2	167.2	+17.3	275		
		+16.2	183.2	+15.2		1,674	
		+31.5	198.5	+16.3	1,136		
		+43.8	210.8	+9.7		203	
		+47.9	214.9	+13.4	18		
		+48.9	215.9	−22.1		171	
		+60.1	227.1	+10.7	200		
		+67.3	234.3	+12.5	446		4,605
Dec. 3 (Naval Observatory).	11 11	−45.5	109.2	−14.0		123	
		0.0	154.7	+6.5	15		
		+11.5	166.2	+17.0		231	
		+29.0	183.7	+15.0		988	
		+43.0	197.7	+16.5	633		
		+51.0	205.7	+10.5		185	
		+60.5	215.2	−22.5		216	
		+77.0	231.7	+11.5		340	2,731
Dec. 4 (Naval Observatory).	11 26	−69.0	72.4	−10.5	9		
		−32.0	109.4	−13.0		108	
		−19.0	122.4	−7.5		31	
		+23.5	164.9	+18.0		185	
		+25.0	166.4	+5.0		25	
		+42.0	183.4	+15.5		1,049	
		+57.0	198.4	+18.0		787	
		+63.5	204.9	+11.5		154	
		+74.0	215.4	−21.5	154		2,502
Dec. 5. (Naval Observatory).	11 12	−86.5	41.8	+5.5	216		
		−52.5	75.8	+2.0	6		
		−19.0	109.3	−13.5		123	
		−4.5	123.8	−8.0	22		
		+25.5	153.8	+8.0	6		
		+37.0	165.3	+18.0		247	
		+38.5	166.8	+5.0		25	
		+39.5	167.8	+9.5		18	
		+56.0	184.3	+15.5		1,142	
		+70.0	198.3	+18.0		741	
		+75.0	203.3	+12.5		154	2,700
Dec. 6 (Naval Observatory).	11 24	−82.5	32.5	−6.0		525	
		−72.5	42.5	+4.5	247		
		−5.5	109.5	−14.0		139	
		+8.5	123.5	−8.5		6	
		+49.5	164.5	+17.5		185	
		+71.5	186.5	+15.0		1,003	
		+82.5	197.5	+17.5	679		2,784
Dec. 7 (Naval Observatory).	10 47	−69.0	33.2	−5.5		972	
		−59.5	42.7	+5.0	216		
		+7.5	109.7	−13.5		185	
		+62.5	164.7	+17.0		154	
		+83.5	185.7	+14.5		849	2,376
Dec. 8 (Naval Observatory).	10 42	−54.0	35.0	−6.0		741	
		−45.5	43.5	+3.5		185	
		+21.5	110.5	−13.5	123		
		+77.5	166.5	+16.0		77	1,126
Dec. 9 (Naval Observatory).	12 9	−84.0	351.1	+5.0	586		
		−39.5	35.6	−6.5		802	
		−31.0	44.1	+3.0		293	
		+33.5	108.6	−14.0		231	1,912
Dec. 10 (Naval Observatory).	12 10	−80.5	341.4	+13.5		154	
		−80.0	341.9	+21.0	46		
		−77.5	344.4	+6.0		1,049	
		−76.5	345.4	−3.5		108	
		−26.5	35.4	−6.0		926	
		−17.5	44.4	+4.5		216	
		+21.5	83.4	+4.5		6	
		+48.0	109.9	−13.0		154	2,659
Dec. 11 (Mount Wilson)	14 0	−73.0	334.7	−5.0		20	
		−69.0	338.7	+13.0		41	
		−65.0	342.7	−11.0	8		
		−65.0	342.7	+22.0	24		
		−61.0	346.7	−5.0		97	
		−60.0	347.7	+5.0		927	
		−17.0	30.7	−8.0		704	
		−5.0	42.7	−6.0		268	
		−5.0	42.7	+3.0		221	
		+5.0	52.7	−5.0	1		
		+36.0	83.7	+2.0		2	
		+62.0	100.7	−14.0		58	2,371

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic: Diff. long.	Heliographic: Longitude	Heliographic: Latitude	Area: Spot	Area: Group	Total area for each day
1929	h. m.	°	°	°			
Dec. 12 (Mount Wilson)	13 30	−80.0	314.8	+8.0	18		
		−63.0	331.8	−4.0		228	
		−58.0	336.8	+13.0		27	
		−54.0	340.8	+21.0	28		
		−50.0	344.8	−11.0		10	
		−49.0	345.8	−4.0		53	
		−48.0	346.8	+5.0		989	
		−5.0	29.8	−8.0		451	
		+9.0	43.8	−5.0		259	
		+9.0	43.8	+4.0		222	
		+17.0	51.8	−5.0		10	
		+49.0	83.8	+2.0		46	
		+78.0	112.8	−14.0	65		2,406
Dec. 13 (Naval Observatory.)	14 21	−80.0	301.2	+14.5		52	
		−66.5	314.7	+10.5	31		
		−41.5	339.7	+14.0	62		
		−41.0	340.2	−2.5		679	
		−38.5	342.7	+21.5	31		
		−36.5	344.7	+7.0		1,080	
		−33.5	347.7	−10.0		15	
		+17.0	38.2	−6.0		910	
		+24.0	45.2	+5.5		247	
		+64.0	85.2	+4.0		77	3,184
Dec. 14 (Naval Observatory.)	10 44	−86.0	264.0	−4.0		139	
		−65.0	305.0	+14.0		25	
		−55.0	315.0	+10.5	31		
		−29.5	340.5	+13.5	62		
		−28.5	341.5	−3.0		772	
		−27.5	342.5	+21.0	31		
		−25.5	344.5	+7.0		1,281	
		−20.0	350.0	−11.0	12		
		+28.5	38.5	−6.5		679	
		+35.0	45.0	+5.0	139		
		+74.0	84.0	+4.5		15	3,186
Dec. 15 (Naval Observatory.)	11 29	−70.5	285.9	−3.5	139		
		−53.0	303.4	+14.5		31	
		−41.0	315.4	+10.0	31		
		−15.5	340.9	+14.0	62		
		−15.0	341.4	−3.0		756	
		−13.5	342.9	+21.5	31		
		−11.5	344.9	+7.5		1,173	
		+42.5	38.9	−6.5		556	
		+49.0	45.4	+5.0	139		2,918
Dec. 16 (Mount Wilson)	14 15	−71.0	270.7	+9.0	10		
		−57.0	284.7	−6.0	95		
		−40.0	301.7	+13.0		5	
		−34.0	307.7	+13.0	2		
		−26.0	315.7	+10.0	15		
		−5.0	336.7	−4.0		379	
		−1.0	340.7	+15.0		42	
		0.0	341.7	+21.0	25		
		+5.0	346.7	+6.0		1,264	
		+7.0	348.7	−4.0		458	
		+10.0	351.7	−10.0		10	
		+51.0	32.7	−8.0		115	
		+66.0	47.7	+4.0	132		
		+69.0	50.7	−5.0	81		2,633
Dec. 17 (Naval Observatory.)	13 59	−85.0	243.7	+9.5	185		
		−55.5	273.2	+10.0	31		
		−42.0	286.7	−4.0	123		
		−23.5	305.2	+14.5		15	
		−12.0	316.7	+9.5	18		
		+13.0	341.7	+14.0		34	
		+13.5	342.2	+21.0	37		
		+14.5	343.2	−3.0		694	
		+17.5	346.2	+7.5		1,065	
		+21.0	349.7	−11.5		46	
		+72.5	41.2	−6.0		247	
		+78.0	46.7	+4.5	154		2,649
Dec. 18 (Mount Wilson)	13 30	−86.0	229.8	+17.0	104		
		−70.0	245.8	+11.0	122		
		−42.0	273.8	+12.0	50		
		−30.0	285.8	+12.0		64	
		−29.0	286.8	−4.0	46		
		−10.0	305.8	+15.0		110	
		0.0	315.8	+9.0		20	
		+23.0	338.8	−3.0		205	
		+26.0	341.8	+13.0	13		
		+26.0	341.8	+21.0	16		
		+33.0	348.8	+6.0		1,055	
		+33.0	348.8	−4.0		319	
		+37.0	352.8	−11.0		12	
		+80.0	35.8	−8.0	109		2,245
Dec. 19 (Naval Observatory).	11 21	−69.0	234.8	+16.5	139		
		−57.5	246.3	+10.5	139		
		−29.5	274.3	+11.0	52		
		−17.0	286.8	+11.5		108	
		−16.5	287.3	−3.0	93		
		+4.0	307.8	+15.0		201	
		+13.5	317.3	+9.5	6		
		+38.0	341.8	+14.0	15		
		+38.5	342.3	+22.0	25		
		+40.5	344.3	−2.5		633	
		+43.0	346.8	+7.5		895	
		+53.0	356.8	−12.0		46	2,362

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1929	h. m.	°	°	°			
Dec. 20 (Naval Observatory).	11 11	−81.5	209.2	+12.0	401	-------	-------
		−80.0	210.7	−19.5	62	-------	-------
		−56.5	234.2	+17.0	-------	154	-------
		−53.0	237.7	+8.0	-------	46	-------
		−42.0	248.7	+10.0	-------	123	-------
		−16.5	274.2	+11.0	62	-------	-------
		−3.0	287.7	+11.5	-------	139	-------
		−3.0	287.7	−3.0	77	-------	-------
		+17.5	308.2	+15.0	-------	262	-------
		+27.0	317.7	+9.5	6	-------	-------
		+51.5	342.2	+14.0	9	-------	-------
		+51.5	342.2	+21.5	22	-------	-------
		+54.0	344.7	−2.0	-------	571	-------
		+57.5	348.2	+7.5	-------	1,049	-------
		+63.0	353.7	−10.5	-------	77	3,060
Dec. 21 (Naval Observatory).	11 17	−83.5	193.9	+12.0	247	-------	-------
		−82.5	194.9	+17.0	540	-------	-------
		−79.0	198.4	+2.5	93	-------	-------
		−68.0	209.4	+11.5	-------	494	-------
		−66.5	210.9	−20.5	62	-------	-------
		−42.5	234.9	+16.5	-------	154	-------
		−38.5	238.9	+7.5	-------	62	-------
		−28.5	248.9	+10.0	-------	123	-------
		−3.5	273.9	+10.5	62	-------	-------
		+11.0	288.4	−3.5	62	-------	-------
		+11.5	288.9	+11.0	-------	139	-------
		+31.0	308.4	+15.0	-------	170	-------
		+65.5	342.9	+21.0	3	-------	-------
		+69.5	346.9	+7.5	-------	741	-------
		+70.0	347.4	−2.5	-------	355	3,307
Dec. 22 (Mount Wilson).	14 25	−80.0	182.5	+5.0	-------	164	-------
		−70.0	192.5	+12.0	-------	301	-------
		−70.0	192.5	+18.0	724	-------	-------
		−65.0	197.5	+3.0	67	-------	-------
		−54.0	208.5	+12.0	-------	896	-------
		−53.0	209.5	−21.0	10	-------	-------
		−45.0	217.5	−18.0	24	-------	-------
		−29.0	233.5	+16.0	153	-------	-------
		−24.0	238.5	+ 8.0	-------	11	-------
		−15.0	247.5	+10.0	-------	50	-------
		0.0	262.5	+13.0	-------	2	-------
		+12.0	274.5	+10.0	-------	99	-------
		+25.0	287.5	−3.0	-------	85	-------
		+26.0	288.5	+10.0	-------	38	-------
		+50.0	312.5	+14.0	-------	121	-------
		+78.0	340.5	+8.0	-------	85	-------
		+83.0	345.5	−3.0	177	-------	-------
		+87.0	349.5	−4.0	180	-------	3,187
Dec. 23 (Yerkes)	11 20	−63.8	187.2	+4.3	-------	218	-------
		−56.5	194.5	+11.0	-------	675	-------
		−56.1	194.9	+16.2	-------	900	-------
		−50.8	200.2	+1.7	38	-------	-------
		−41.2	209.8	+10.8	-------	479	-------
		−31.7	219.3	−18.0	26	-------	-------
		−17.0	234.0	+15.2	209	-------	-------
		−2.5	248.5	+9.4	-------	37	-------
		+23.5	274.5	+10.0	58	-------	-------
		+36.8	287.8	−3.5	75	-------	-------
		+62.1	313.1	+14.8	109	-------	2,824
Dec. 24 (Naval Observatory).	11 33	−75.0	162.8	−13.5	3	-------	-------
		−54.5	183.3	+18.5	6	-------	-------
		−49.5	188.3	+5.0	-------	262	-------
		−35.5	202.3	+13.5	-------	1,636	-------
		−13.5	224.3	+15.5	3	-------	-------
		−3.5	234.3	+16.0	108	-------	-------
		+11.5	249.3	+9.5	-------	31	-------
		+25.5	263.3	+14.0	-------	93	-------
		+37.5	275.3	+11.5	-------	62	-------
		+49.5	287.3	+10.5	-------	25	-------
		+51.5	289.3	−3.0	77	-------	-------
		+76.5	314.3	+15.5	108	-------	2,414
Dec. 25 (Mount Wilson)	14 0	−60.0	163.3	−13.0	7	-------	-------
		−37.0	186.3	+5.0	-------	144	-------
		−30.0	193.3	+18.0	-------	580	-------
		−30.0	193.3	+12.0	-------	208	-------
		−25.0	198.3	+13.0	-------	19	-------
		−23.0	200.3	+3.0	13	-------	-------
		−14.0	209.3	+13.0	-------	433	-------
		+10.0	233.3	+16.0	147	-------	-------
		+40.0	263.3	+13.0	-------	95	-------
		+51.0	274.3	+11.0	32	-------	-------
		+66.0	289.3	−3.0	61	-------	-------
		+64.0	287.3	+9.0	-------	10	1,749
Dec. 26 (Naval Observatory).	10 53	−47.0	164.8	−14.0	6	-------	-------
		−28.0	183.8	+18.0	6	-------	-------
		−22.5	189.3	+4.0	-------	216	-------
		−10.0	201.8	+14.0	-------	1,373	-------
		+22.5	234.3	+16.0	123	-------	-------
		+34.5	246.3	−15.5	9	-------	-------
		+52.5	264.3	+13.0	-------	231	-------
		+63.5	275.3	+10.5	46	-------	-------
		+76.5	288.3	−3.5	93	-------	2,103
Dec. 27 (Mount Wilson)	11 30	−10.0	188.3	+5.0	-------	131	-------
		−3.0	195.3	+17.0	-------	792	-------
		−3.0	195.3	+12.0	-------	204	-------
		+3.0	201.3	+14.0	-------	28	-------
		+16.0	214.3	+11.0	-------	221	-------
		+38.0	236.3	+16.0	-------	157	-------
		+67.0	265.3	+13.0	-------	198	-------
		+77.0	275.3	+9.0	19	-------	1,840
Dec. 28 (Naval Observatory).	13 54	−74.5	109.3	−12.0	22	-------	-------
		0.0	183.8	+18.0	3	-------	-------
		+5.5	189.3	+3.5	-------	154	-------
		+14.5	198.3	+15.0	-------	926	-------
		+51.0	234.8	+16.5	93	-------	-------
		+81.0	264.8	+14.0	-------	231	1,429
Dec. 29 Naval (Observatory).	12 17	−20.5	142.0	+12.0	-------	22	-------
		−9.5	162.0	+10.5	6	-------	-------
		+18.5	190.0	+3.0	-------	93	-------
		+25.5	197.0	+14.5	-------	725	-------
		+63.5	235.0	+16.5	77	-------	923
Dec. 30 (Naval Observatory).	11 47	−45.5	113.1	−12.5	6	-------	-------
		−17.0	141.6	+12.5	-------	46	-------
		+32.0	190.6	+5.0	-------	62	-------
		+37.0	195.6	+15.5	-------	694	-------
		+77.5	236.1	+16.5	77	-------	885
Dec. 31 (Naval Observatory).	10 48	−2.5	143.5	+11.5	-------	62	-------
		+43.5	189.5	+5.5	6	-------	-------
		+49.0	195.0	+16.0	-------	525	593
Mean daily area for December.	-------	-------	-------	-------	-------	-------	2,410

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR DECEMBER, 1929[1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland, January 4, 1930]

December, 1929	Relative numbers	December, 1929	Relative numbers	December, 1929	Relative numbers
1	b d 140	11	a 96	21	145
2	a 125	12	b 128	22	120
3	122	13	139	23	Mac 126
4	98	14	Ec 137	24	a 118
5	86	15	139	25	132
6	d d	16	b b	26	b
7	a 43	17	b b	27	b
8	56	18	137	28	a 91
9	57	19	a 139	29	71
10	d d 54	20	a d 133	30	Mc 64
				31	a 36

Mean, 26 days 105.1.

[1] Dependent alone on observations at Zurich and its station at Arosa.
a = Passage of an average-sized group through the central meridian.
b = Passage of a large-sized group through the central meridian.
c = New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk, W, on the western part, M, in the central zone.
d = Entrance of a large or average-sized center of activity on the eastern limb.

AEROLOGICAL OBSERVATIONS

By RICHMOND T. ZOCH

Free-air temperatures were close to normal at Groesbeck and Broken Arrow and mostly below normal at Ellendale and Due West. At Royal Center free-air temperatures were below normal near the surface and above normal at higher levels. (Table 1.)

At the higher levels at Groesbeck and Due West free-air relative humidities were below normal and at all other stations they were mostly above normal.

Free-air vapor-pressures were above normal in the lower levels at Groesbeck and Broken Arrow and in the higher levels at Royal Center. In all other cases they were below normal.

Table 2 is not closely comparable with Table 1 because flights were made at the Naval Air stations on comparatively few days during the month.

The resultant winds were variable in the lower levels throughout the United States. At the 1,000-meter level they were westerly. At higher levels they veered to northwesterly. (Table 3.)

The number of flights (Table 4) made during the month was larger than usual on account of the series made on the 27th and 28th, at which time a special sounding-balloon series was made at 10 other stations.

TABLE 4.—*Observations by means of kites, captive and limited-height sounding balloons during December, 1929*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), M. S. L., reached during month	2,678	2,579	2,630	2,270	2,390
Maximum altitude (meters), M. S. L., reached and date	[1] 4,536	[2] 5,036	[3] 5,501	[4] 3,807	[5] 4,333
Number of flights made	33	38	37	31	36
Number of days on which flights were made	24	29	27	23	28

[1] 27th. [2] 31st. [3] 5th. [4] 30th. [5] 28th.

In addition to the above there are approximately 120 pilot balloon observations made daily at some 50 Weather Bureau stations in the United States.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during December, 1929*

TEMPERATURE (°C.)

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Meters										
Surface	3.7	−0.5	5.6	−2.1	−10.4	−0.9	9.1	0.0	−3.6	−1.9
500	4.2	+0.5	5.9	−1.6	−10.5	−1.1	9.0	+0.5	−4.0	−0.9
1,000	4.0	+0.8	5.3	−1.6	−7.7	−0.7	8.6	+0.2	−2.7	+1.0
1,500	3.6	+0.8	4.4	−1.2	−6.5	0.0	7.5	0.0	−3.1	+0.8
2,000	1.3	−0.2	3.0	−1.0	−8.6	−1.0	5.8	−0.2	−4.2	+0.9
2,500	−0.8	−0.3	1.1	−1.0	−10.7	−1.1	3.2	−0.8	−6.4	+0.5
3,000	−2.6	+0.2	−0.9	−0.8	−13.2	−1.1	1.2	−0.5	−8.7	+0.4
4,000	−10.1	−2.0	−5.5	+0.1	−17.6	0.0			−13.9	+0.9
5,000			−12.1	+0.1	−24.7	−1.2				

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during December, 1929*—Continued

RELATIVE HUMIDITY (%)

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Meters—Continued										
Surface	71	+1	78	+5	81	0	80	+6	87	+7
500	62	−2	65	0	79	0	70	+3	84	+7
1,000	54	+1	59	0	68	+3	54	−3	74	+8
1,500	44	+1	48	−7	59	+1	42	−7	64	+8
2,000	41	+3	40	−11	57	+2	28	−14	59	+7
2,500	39	+3	38	−8	55	0	21	−18	54	+3
3,000	37	+1	39	−3	57	+3	21	−15	49	−2
4,000	63	+29	38	−3	33	−20			51	−1
5,000			38	−3	44	−2				

VAPOR PRESSURE (*mb.*)

Altitude m. s. l.	Broken Arrow, Okla. Mean	Departure from normal	Due West, S. C. Mean	Departure from normal	Ellendale, N. Dak. Mean	Departure from normal	Groesbeck, Tex. Mean	Departure from normal	Royal Center, Ind. Mean	Departure from normal
Surface	6.50	+0.23	7.73	−0.63	2.34	−0.34	11.11	+1.68	4.57	−0.06
500	5.88	+0.31	6.61	−0.90	2.31	−0.33	9.67	+1.35	4.31	+0.26
1,000	4.68	+0.20	5.72	−0.76	2.31	−0.10	6.98	+0.21	4.01	+0.68
1,500	3.14	−0.45	4.39	−1.06	2.18	−0.01	4.67	−0.59	3.19	+0.45
2,000	2.44	−0.47	3.22	−1.15	1.75	−0.12	2.42	−1.54	2.76	+0.47
2,500	1.96	−0.42	2.57	−0.88	1.40	−0.18	1.05	−2.11	2.22	+0.26
3,000	1.65	−0.36	2.16	−0.61	1.13	−0.13	0.80	−1.74	1.85	+0.15
4,000	1.39	−0.06	1.70	−0.29	0.02	−0.76			1.57	+0.38
5,000			1.37	−0.29						

TABLE 2.—*Free air data determined at naval air stations during December, 1929*

Altitude m. s. l.	Temperature (° C.)			Relative humidity (%)		
	Pensacola- Fla.	San Diego, Calif.	Washington, D. C.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
(*Meters*)						
Surface	6.4	17.5	−0.3	88	58	75
500	7.6	16.7	0.9	75	47	65
1,000	8.0	16.7	0.3	66	32	61
2,000	6.2	12.9	−2.1	51	22	60
3,000	3.1		−5.6	43		50
4,000			−10.4			60

TABLE 3.—*Free-air resultant winds (m. p. s.) based on pilot balloon observations made near 7 a. m. (e. s. t.) during December, 1929*

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,868 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (65 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (40 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Meters	°		°		°		°		°		°		°		°		°		°	
Surface	S. 36 W.	1.5	S. 13 W.	1.4	N. 82 W.	5.7	S. 60 W.	2.4	N. 38 W.	3.1	S. 30 W.	0.9	S. 65 W.	2.4	N. 17 W.	1.7	N. 46 E.	3.3	N. 55 W.	2.2
500	S. 61 W.	5.4	S. 54 W.	3.6			N. 87 W.	8.2	N. 39 W.	3.9	S. 42 W.	5.1			N. 63 W.	2.1	N. 79 E.	6.9	N. 31 E.	0.6
1,000	S. 82 W.	8.3	S. 79 W.	5.9			N. 85 W.	8.6	N. 35 W.	8.1	N. 80 W.	5.7	S. 67 W.	7.1	S. 70 W.	4.2	N. 88 E.	5.5	N. 8 E.	1.5
1,500	N. 69 W.	6.7	N. 89 W.	9.2			N. 84 W.	9.5	N. 37 W.	10.8	N. 71 W.	6.4	S. 89 W.	10.9	S. 88 W.	5.9	S. 63 E.	3.4	N. 9 W.	2.0
2,000	N. 74 W.	10.4	N. 86 W.	11.6	N. 79 W.	8.5	N. 88 W.	11.6	N. 43 W.	11.3	N. 81 W.	7.8	N. 80 W.	11.5	S. 83 W.	7.0	S. 65 E.	2.0	N. 33 W.	2.8
2,500	N. 67 W.	11.0	N. 89 W.	12.3	N. 72 W.	14.2	N. 84 W.	12.5	N. 52 W.	11.6	S. 89 W.	8.4	N. 69 W.	15.7	S. 85 W.	9.7	S. 5 E.	1.0	N. 44 W.	3.5
3,000	N. 62 W.	12.1	N. 70 W.	14.5	N. 66 W.	13.3	N. 82 W.	15.0	N. 52 W.	13.6	N. 87 W.	10.2	N. 63 W.	20.3	S. 86 W.	11.1	S. 27 W.	1.7	N. 49 W.	4.8
4,000	N. 29 W.	16.3	S. 80 W.	4.7	N. 64 W.	9.3	N. 85 W.	19.6	N. 54 W.	9.4	N. 54 W.	10.9			S. 88 W.	11.1	N. 84 W.	1.8	N. 43 W.	6.9
5,000	N. 45 W.	9.0			N. 2 W.	6.7	N. 81 W.	24.3	N. 68 W.	12.0	N. 45 W.	12.0			N. 80 W.	9.6	N. 59 W.	3.3		

Altitude m. s. l.	Medford, Oreg. (446 meters)		Memphis, Tenn. (145 meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (313 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,280 meters)		San Francisco, Calif. (60 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (67 meters)		Washington, D. C. (34 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Meters	°		°		°		°		°		°		°		°		°		°	
Surface	S. 5 W.	0.4	S. 41 W.	2.9	N. 17 W.	0.8	N. 42 W.	1.0	S. 50 W.	2.4	S. 13 E.	2.5	S. 27 E.	0.9	N. 67 E.	1.3	S. 48 E.	1.6	S. 49 W.	0.7
500	S. 3 W.	0.5	S. 71 W.	9.3	N. 54 W.	1.1	N. 56 W.	4.8	S. 74 W.	5.6			N. 71 E.	1.3	N. 47 E.	2.9	S. 19 W.	5.2	N. 89 W.	7.1
1,000	S. 16 W.	2.3	S. 83 W.	10.2	S. 86 W.	2.0	N. 51 W.	9.5	S. 86 W.	8.4			N. 13 E.	0.7	N. 16 W.	3.4	S. 31 W.	6.9	N. 78 W.	8.5
1,500	S. 38 W.	2.5	N. 73 W.	9.7	S. 84 W.	4.2	N. 56 W.	10.9	N. 87 W.	8.8	S. 3 E.	5.0	N. 32 W.	2.3	N. 40 W.	6.8	S. 58 W.	8.2	N. 78 W.	12.4
2,000	N. 76 W.	2.6	N. 49 W.	11.7	N. 64 W.	7.8	N. 56 W.	11.5	N. 77 W.	11.8	S. 20 W.	3.6	N. 33 W.	2.1	N. 75 W.	5.4	S. 68 W.	6.0	N. 85 W.	12.4
2,500	N. 31 W.	4.3	W.	12.0	N. 64 W.	7.9	N. 57 W.	12.2	N. 89 W.	13.5	S. 86 W.	3.4	N. 16 W.	3.2	S. 67 W.	7.1	N. 87 W.	10.3	S. 75 W.	15.7
3,000	N. 48 W.	7.8					N. 58 W.	13.0	S. 68 E.	9.0	N. 47 W.	5.8	N. 79 W.	3.9			S. 67 W.	7.0	S. 80 W.	17.0
4,000	N. 27 W.	3.9					N. 43 W.	12.0			N. 70 W.	10.1	N. 68 E.	6.0			W.	6.0		
5,000							E.	7.0			N. 82 W.	10.2								

AEROLOGICAL OBSERVATIONS FOR THE YEAR 1929

By RICHMOND T. ZOCH

Free-air temperatures for the year were below normal at all levels at all stations. (Table 1.) In most cases, especially at the lower levels, the departures were moderately large.

Free-air relative-humidity departures were of small magnitude. The were variable at Ellendale and Groesbeck, positive at all levels at Broken Arrow and Royal Center and at most levels at Due West.

Vapor-pressure departures were mostly negative, except at Due West and in the upper levels at Broken Arrow. They were mostly of moderate magnitude.

Table 2 contains a summary of the upper-air observations made during the year. In addition to the observations indicated in this table there were 34 sounding-balloon observations made at Broken Arrow and 40 made at 10 other Weather Bureau stations in connection with the International Month, December, 1929.

There were 52 pilot-balloon stations operating at the close of the year.

TABLE 2.—*Observations by means of kites, captive and limited-height sounding balloons during the year 1929* [1]

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes, M. S. L., reached during year	2,571	2,313	2,715	2,291	2,022
Maximum altitude, M. S. L., reached and date	[2] 6,131	[3] 5,036	[4] 5,588	[5] 5,930	[6] 5,103
Number of kite flights made	299	268	334	291	285
Number of captive balloon flights made	3	37	1	1	13
Number of limited height sounding balloon flights made	29	3	18	13	1
Number of days on which flights were made	313	284	319	290	284

[1] There were approximately 40,000 pilot-balloon observations made during the year.
[2] Nov. 22.
[3] Dec. 31.
[4] Apr. 28.
[5] Apr. 12.
[6] May 27.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during year 1929*

Altitude m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
	TEMPERATURE (° C.)									
Meters										
Surface	14.0	−1.5	15.6	−1.2	4.6	−0.9	16.1	−1.9	8.9	−2.1
500	12.8	−1.3	14.2	−0.6	4.4	−1.0	15.2	−1.0	7.1	−1.8
1,000	11.4	−0.9	12.2	−0.3	3.5	−1.0	13.9	−0.7	5.2	−1.5
1,500	9.6	−0.9	9.9	−0.2	2.1	−1.1	12.3	−0.6	3.4	−1.3
2,000	7.4	−0.9	7.6	−0.1	−0.2	−1.2	10.2	−0.6	1.4	−1.2
2,500	4.8	−0.9	5.1	−0.2	−2.8	−1.2	7.7	−0.7	−0.8	−1.1
3,000	2.2	−0.7	2.7	−0.1	−5.5	−1.1	5.1	−0.7	−3.4	−1.2
4,000	−3.2	−0.4	−3.1	−0.4	−10.7	−0.7	−0.6	−0.9	−9.0	−1.6
5,000	−8.7	−0.3	−9.7	−1.5	−16.3	−0.7	−7.3	−2.0	−14.9	−1.5
	RELATIVE HUMIDITY (PER CENT)									
Meters										
Surface	70	+2	72	+6	68	−4	80	+6	74	+4
500	68	+3	68	+3	67	−3	73	+2	73	+4
1,000	62	+2	66	+2	61	−2	62	−1	69	+4
1,500	58	+3	65	+2	58	0	54	−1	63	+3
2,000	54	+3	62	+2	56	0	49	0	57	+1
2,500	53	+5	59	+2	55	0	47	+2	54	+2
3,000	52	+5	55	+1	56	+2	45	+3	54	+4
4,000	48	+4	41	−10	48	−4	44	+4	52	+6
5,000	48	+7	41	−5	53	+3	29	−7	52	+7
	VAPOR PRESSURE (mb.)									
Meters										
Surface	13.29	−0.47	14.43	+0.43	7.30	−0.75	16.44	−0.36	10.19	−0.60
500	11.92	−0.25	12.59	+0.22	7.12	−0.72	14.15	−0.53	8.98	−0.39
1,000	9.80	−0.18	10.72	+0.27	5.73	−0.63	10.87	−0.73	7.47	−0.30
1,500	7.95	−0.11	9.08	+0.44	4.75	−0.50	8.17	−0.89	5.93	−0.36
2,000	6.28	−0.06	7.28	+0.40	3.85	−0.44	6.46	−0.55	4.63	−0.31
2,500	5.07	+0.10	5.79	+0.36	3.10	−0.41	5.27	−0.30	3.63	−0.15
3,000	4.09	+0.15	4.58	+0.27	2.56	−0.27	4.31	−0.16	2.98	+0.03
4,000	2.82	+0.37	2.11	−0.71	1.56	−0.26	3.14	+0.17	1.88	+0.12
5,000	2.55	+0.94	1.78	−0.02	1.26	+0.08	1.94	−0.20		

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By P. C. DAY

GENERAL SUMMARY

The chief features of the weather for December, 1929, were the severe cold during the early part of the third decade over the interior valleys; the excessive precipitation over portions of southern Florida on the 10th and 11th; the breaking of the prolonged drought in the far Northwest near the end of the first decade; and the unusual and protracted prevalence of fog over many of the interior and eastern districts near the middle of the month.

PRESSURE AND WINDS

The month opened with cyclonic conditions existing in the Great Plains and with light snow from Montana eastward and southeastward to the Mississippi Valley and portions of the upper Lake region. By the morning of the 2d the cyclonic conditions had separated into two distinct areas, one central over Lake Huron and the other over the northern Gulf region, and precipitation covered the intervening areas from the eastern Plains to near the Atlantic coast, snow continuing over the northern districts and rain in the Central and Southern States. During the following day the precipitation area moved off the Atlantic coast, and fair weather had become established in most districts to the west, continuing in practically all districts until the morning of the 7th.

On that date slight precipitation was recorded at a few points in the far Northwest, followed at a few other points in that region by additional precipitation on the 8th and by the 9th precipitation had overspread the entire region from central California northward and to the eastward as far as the Rocky Mountains, thus ending the long period of drought in that region.

During this period general but mostly light precipitation occurred over much of the eastern part of the country, some snow falling along the northern border. Following the 9th precipitation continued in the far Northwest, the rains becoming heavy at a few points near the coast and the precipitation changed to snow as the area moved eastward into the near-by mountain regions.

By the morning of the 11th precipitation had extended eastward, and light snow or rain fell over extensive areas along the northern border, continuing during the 11th, 12th, and 13th over portions of the same area.

On the morning of the 14th precipitation again became heavy at points near the north Pacific coast, while to the eastward there were occasional rains with local snows in a few more northern sections. At the same time fog was reported from many Central and Eastern States, continuing with some precipitation during the 16th and 17th. On the last-mentioned date an extensive storm area had moved to the southern Plains and generally light precipitation had overspread much of the country from the far Northwest eastward and southeastward to the Appalachian Mountains. By the morning of the 18th the precipitation had become heavy in many central districts and rain had changed to snow from the lower Missouri Valley eastward to the Lake region and to snow or sleet in portions of the Ohio Valley, while fog continued over many Atlantic coast districts to which precipitation had now extended. On the 19th snow continued in the districts from the lower Mississippi Valley eastward to the Middle Gulf States, snow reaching southward to the middle of those States and precipitation, mostly rain, covered all eastern districts, fog continuing over many middle and north Atlantic coast districts, the storm continuing during the 20th over a large area from the lower Mississippi Valley northeast to New England and disappearing over the lower St. Lawrence Valley, during the 21st.

About the 18th to 20th considerable precipitation occurred in the far West, gradually extending eastward into the Rocky Mountains, and by Saturday, December 21, snow had set in over central Texas which continued during the following day, extending northeastward into Tennessee, and by the morning of the 21st had reached the eastern portions of the Carolinas, and precipitation was occurring from the southern and middle Mississippi Valley and the southern Lake region eastward to the Atlantic coast, snow falling in the Ohio Valley and near-by areas, while rains had fallen near the Atlantic coast. This storm passed rapidly to southern New England by the 24th, attended by some local heavy snows, and moved thence northeastward over the near-by Canadian Provinces on Christmas Day.

On the 25th light rains overspread the north Pacific coast and centered in the same general area for several days, but otherwise in the far West there was little precipitation during the closing days of the month and there was generally no important precipitation during this period over the other portions of the country.

The distribution of the monthly means of pressure for the United States and Canada is graphically shown on Chart No. VI of this REVIEW, and the departures of these from the normal and their changes from the preceding month are likewise shown on the insets to Charts II and III of the same publication.

Generally speaking, there were few cyclonic storms of sufficient intensity to cause damaging winds over extensive areas and hence such storms were infrequent, as shown by the few instances recorded in the table at the end of this section.

Important ice or glaze storms, however, occurred over several extensive areas where damage was caused by the breaking of trees and shrubs from the heavy accumulations of ice, or where overhead wires of all kinds were damaged by the loads of ice carried.

These glaze or ice storms occurred as far south as the vicinity of Corpus Christi, Tex., and northward as far as Buffalo and Oswego, N. Y., and were extensively destructive in certain localities between. Special mention may be made of these storms in portions of western New York on the 17th and 18th, when untold damage occurred to trees which will take years to repair, and great damage resulted to overhead wires of all kinds. Similar storms on the same dates caused much damage over wide areas in southern Michigan and portions of Illinois, Indiana, and Ohio, while even as far south as Texas damage to wires resulted from these storms and cattle suffered severely from the attending icy conditions.

TEMPERATURE

During the greater part of the month temperatures were moderate and the daily changes were chiefly unimportant and frequently not as much as 20°. Important changes occurred during the first three days, the temperature falling to fairly low points in the Northwest and Central States and rising to normal or above over eastern districts. The week ended December 10 was mainly moderate, though distinctly warm for midwinter in some southern and most western districts.

The week ended December 17 was warmer than normal over the greater part of the country, in fact, it was unusually warm in all central and southern districts, the weekly departures from their normals ranging up to 10° to 20° or more over a wide area extending from the East Gulf States to the northern Plateau, the only section having temperatures below the normal being small areas along the extreme northern border.

The week ending December 24, however, had some sharp changes in temperature and was decidedly cold over most central and eastern districts during the first few days. The averages for the week were below normal from the Rocky Mountains to the Mississippi Valley, but they were moderately above normal over the middle Atlantic coast and generally to westward of the Plateau region. The final week was warm for the season, the weekly means averaging well above normal over all interior and northern districts, the departures ranging from +15° to +18° along the northern border to smaller values along the Mexican border and over the west Gulf States. The only portions having temperatures below the normal were a small area over the Southeastern States and a similar area along the middle Pacific coast.

For the month as a whole the temperatures were above the normal over the greater part of the United States, but in Canada there appear to have been considerable areas with monthly means below normal, though the departures seem not to have been large. Over the Missouri Valley and thence eastward to the Atlantic coast the temperatures were generally below the normal and similar conditions existed over most of the Gulf States. Elsewhere the temperatures were above normal, the month being particularly warm in the districts from the Rocky Mountains westward to the Pacific; in portions of this area, notably the central Rocky Mountains and sections near by, both east and west, the mean temperatures were among the highest of record and in a few instances they were materially higher than during the preceding November.

The extremes of temperature were mainly within the usual range, the maximum rising to 90° only in Florida and California, while along the northern border they were mainly not higher than 60°. Minimum temperatures below zero occurred at some points in all the States save a few in the extreme Southeast and in California and Washington. The lowest reported was −47° at a point in the mountains of Montana and they were below zero at points as far south as Texas and Louisiana.

PRECIPITATION

December brought less than normal precipitation to about two-thirds of the States. From the Ohio River southward to the Gulf the deficiencies were considerable, and for the most part the middle and southern Plains received much less than normal, but these regions usually had received sufficient precipitation during November preceding.

Several Atlantic Coast States and all of the middle Rocky Mountain region failed to receive the normal December quantities, yet almost everywhere had enough moisture for present needs. In the far Southwest and over most of the middle Plateau the situation was less fortunate, for the precipitation shortage noted before December began became still more marked, Arizona and southern California especially receiving no moisture of importance before the year ended.

The unusually protracted drought in the northern half of California and throughout Oregon and Washington was wholly or considerably relieved by liberal precipitation, mainly rain, which started late in the first decade of December. In Oregon the precipitation averaged more than 50 per cent above normal; this was the first month since March, 1928, to have an average precipitation as great as 5 inches, and only the fourth month since that one to furnish the State more rain than the normal for the month.

The States of the northern border, from Washington eastward to North Dakota, recorded an excess of precipitation, most of Montana registering nearly, or more than, twice the normal. Central and northern Indiana and large parts of the States adjoining received more than normal and excesses were reported from many parts of New York and New England, and from the southeastern portions of the Carolinas.

In Florida the rainfall averaged about normal for the month, but the distribution was irregular. Miami recorded over 9 inches, or over five times the December normal. About three-fifths of this monthly amount occurred on the 10th and 11th, in the heaviest rain of local record for any December. This was the fourth time since the middle of September that a quantity exceeding 4 inches was measured within the space of 24 hours at the Miami station.

SNOWFALL

Two positive features of December's snowfall deserve special comment. One is the marked southward extension of the area in which snow of importance occurred. From central Texas eastward to Georgia depths of from 3 to 20 inches were noted over most interior counties, and traces of snow reached the Gulf coast, all or almost all in connection with the storm of the 20th to 22d. The other feature was the heavy snowfall of the 18th to 20th over most of the Lake region and the northern part of the Ohio Valley. The snow here drifted badly and serious blocking of highways resulted.

From the southern portion of the upper Lakes southeastward to the central Appalachians the month's snowfall was considerably greater than the average December quantity; while the States bordering the Gulf from Texas to Alabama reported the greatest average snowfall of December record, some of them receiving many times more than in any previous December.

The leading negative feature was the scarcity, and for many districts the complete absence of snowfall in the higher portions of the far Southwest. Almost all portions of Arizona and southern California either received no snowfall whatever or decidedly little in comparison with what is expected.

The situation was similar, though not so notable, further to northward and northeastward. From southern Colorado westward to north-central California practically all high areas received very much less than the normal December quantity of snow.

The outlook for water flow in the West next summer was not favorable at the end of December, save in a few northern districts. However, snowfall during January has greatly improved the situation in many of the western States.

Nearly all portions of the Plains recorded less snowfall in December than normal, and some central portions very much less. In the Atlantic States the December snowfall varied considerably but usually exceeded the normal, especially in the portions most remote from the coast.

HUMIDITY AND CLOUDS

The percentage of the relative humidity was mainly above the normal from the Missouri Valley eastward and

southeastward to the Lake region and Ohio Valley, locally in portions of the Atlantic and Gulf States and along the Pacific coast. There were wide deficiencies in most of the Rocky Mountain and Plateau regions and in the nearby southern Great Plains.

The most notable fact in connection with the record of the state of the weather was the extent of fog over wide areas and its persistence during the middle period of the month. This condition was particularly observed over much of the Middle West from near the end of the first decade, continuing in some cases daily in that region and extending over wide regions eastward and southeastward to the Atlantic coast until well after the middle of the month. In portions of these areas dense fog existed continuously for a week or more exceeding in some localities any previous record of such conditions in the weather history of the places. Much cloudy weather, with frequent, though mainly light precipitation, prevailed in many regions covering the eastern two-thirds of the country, particularly over the Lake regions and to the eastward and into the near-by areas.

SEVERE LOCAL STORMS, DECEMBER, 1929

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
New York (western)	7–8					Ice	Some damage to telephone and power lines; auto traffic made hazardous.	Official, U. S. Weather Bureau.
Fort Smith, Ark	17	2:45 p. m.				Tornado	Slight damage over path one-fourth mile long	Do.
Grannis, Ark	17	3:30 p. m.	8			do	Slight property damage	Do.
Ville Platte, La. (10 miles east of).	17	11 p. m.	100–150		$6,000	do	Buildings and a cotton gin damaged	Do.
Illinois, Indiana, and Ohio (northern parts) of southern Michigan and western New York.	17–19					Ice, snow, and wind.	Public utilities badly crippled; trees broken; highways obstructed; numerous accidents. The storm was particularly severe in Buffalo and vicinity.	Do.
Tupelo, Miss	18	3 a. m.				Tornado	A garage wrecked	Do.
Georgia (central)	22					Snow and ice	Considerable damage to telephone and telegraph poles and wires, trees, and shrubbery.	Do.
Washington (western)	25			1		Wind	Wires, signs, poles, trees, small craft, and buildings damaged.	Do.

RIVERS AND FLOODS

By R. E. SPENCER

No floods of importance occurred in the rivers of the United States during December, 1929. Flood stages were reached or slightly exceeded in several districts, as indicated in the table following, but no damage of consequence occurred.

Flood stage and crest data

[All dates in December unless otherwise specified]

River and station	Flood stage	Above flood stages—dates: From—	Above flood stages—dates: To—	Crest: Stage	Crest: Date
ATLANTIC DRAINAGE	*Feet*			*Feet*	
Neuse: Smithfield, N. C	14	4	4	14.0	4
Cape Fear: Elizabethtown, N. C	22	5	6	24.0	5
Peedee:					
Mars Bluff, S. C	17	(1)	1	17.0	Nov. 30–Dec. 1
		5	11	19.0	8
Poston, S. C	18	8	13	18.8	10
Santee:					
Rimini, S. C	12	(1)	11	14.6	10
		16	22	12.8	21–22
Ferguson, S. C	12	(1)	(2)	21.0	Oct. 7
Saluda: Chappells, S. C	14	4	4	14.4	4
EAST GULF DRAINAGE					
Tombigbee: Lock No. 4, Demopolis, Ala	39	(1)	4	63.7	Nov. 21–22
Pearl: Jackson, Miss	20	(1)	1	25.8	Nov. 23–26
West Pearl: Pearl River, La	13	(1)	12	16.3	Nov. 18
GREAT LAKES DRAINAGE					
Maumee: Fort Wayne, Ind	15	18	20	16.5	18
St. Joseph: Montpelier, Ohio	10	19		10.4	19

[1] Continued from last month. [2] Continued at end of month.

Flood stage and crest data—Continued

River and station	Flood stage	Above flood stages—dates: From—	Above flood stages—dates: To—	Crest: Stage	Crest: Date
MISSISSIPPI DRAINAGE	*Feet*			*Feet*	
Walhonding: Walhonding, Ohio	8	18	19	9.3	19
Scioto:					
Larue, Ohio	11	14	14	12.3	14
		18	19	12.7	18
Bellpoint, Ohio	9	21	21	9.3	21
Circleville, Ohio	10	15	15	10.3	15
		19	20	12.9	19
Chillicothe, Ohio	16	20	21	17.6	21
Wabash:					
Lafayette, Ind	13	19	21	16.5	19
Covington, Ind	16	17	22	19.7	20–21
Terre Haute, Ind	16	18	23	16.8	20–21
Vincennes, Ind	14	25	26	14.3	26
Mount Carmel, Ill	16	20	29	19.5	27
White: Decker, Ind	18	24	26	18.5	26
White, East Fork: Seymour, Ind	10	19	20	11.0	20
White, West Fork:					
Elliston, Ind	19	18	22	22.3	20
Edwardsport, Ind	15	18	24	18.3	23
Illinois: Peru, Ill	14	3	6	14.7	5
		22	22	14.2	22
		26	28	14.6	27
St. Francis:					
Fisk, Mo	20	19	21	22.0	20
St. Francis, Ark	18	24	25	18.3	25
Black: Corning, Ark	11	18	27	12.5	22
Sulphur: Ringo Crossing, Tex	20	17	17	22.0	17
PACIFIC DRAINAGE					
Willamette:					
Eugene, Oreg	12	19	19	14.0	19
Harrisburg, Oreg	10	19	20	14.4	19
Albany, Oreg	20	21	21	20.9	21
Willamette, Coast Fork: Saginaw, Oreg	9	18	19	10.0	18
Santiam: Jefferson, Oreg	10	15	15	11.0	15
		19	19	13.8	19

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, DECEMBER, 1929

By J. B. KINCER

General summary.—During the first decade frosts and freezing weather overspread the more southern States and did more or less harm to winter truck in the Gulf section, but a reaction to warmer about the 10th was favorable and some recovery was reported. Rains in the Florida Peninsula were beneficial in relieving the drought that had prevailed for some time, while the general snow that was deposited during the first part of the month in more northern portions disappeared from nearly all the principal winter wheat area. Toward the latter part of the decade generous rains fell in the droughty sections of the West, especially heavy falls being reported from coast districts, while rather heavy snows occurred over the northwestern Great Plains.

During the second decade mild weather throughout the central valley States, attended by considerable moisture, made fields soft and muddy and little outside work could be performed. The main winter wheat belt was generally bare of snow; in more southern sections winter truck showed rapid recovery from the effects of the previous freeze. Further rains in the far West greatly improved conditions in the northern part, but it continued dry in southern districts. During the last part of the decade there was a marked reaction to colder and outside operations were not very active.

The last decade of the month was much warmer throughout the interior of the country, which permitted more active field operations. The snow cover disappeared rapidly except over the more northern districts, while truck showed improvement in the west Gulf area. The warmer weather and absence of storms were favorable for livestock, though there was much need of snow on ranges in some sections.

Small grains.—Winter wheat was well protected during the severe weather of the first decade, but toward the latter part of the period the snow cover disappeared from nearly all of the main belt; very little injury was apparent from the cold. Oats were damaged by the freeze in the Southeast, while moisture was needed in parts of the West, although the Pacific Northwest had general rains; the moisture in the latter area was beneficial, but was too late to save large acreages. Winter wheat remained in satisfactory condition during the second decade, despite the variable weather, which checked growth in places. During the last decade the ground was bare over practically the entire wheat area, but the general condition of grains remained satisfactory, except for some further damage to oats in the Southeast.

Corn and cotton.—The variable weather in the Corn Belt caused marked variations in gathering the remaining crop; there were some complaints of grain spoiling in fields and cribs, but molding was mostly checked by cold weather.

Gathering the remaining cotton crop was largely completed during the month, with but little unpicked at the close.

Miscellaneous crops.—Meadows remained in generally satisfactory condition throughout the month. The cold weather caused some suffering among livestock in the northern Great Plains, but at the close the open range permitted free grazing. The absence of water in the central Rocky Mountain region necessitated long drives of livestock, which was detrimental, but the rains in the Pacific Northwest caused good growth of grass; ranges were still poor in the far Southwest.

There was considerable damage to truck during the month, especially to cabbage and to tender varieties which were injured or killed south to southern Florida. Sugarcane in Louisiana showed some deterioration due to the warmth, following the freeze. Citrus continued to do well generally, with no extensive damage reported.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The weather over the steamer lanes was exceptionally severe during the first and last decades of the month, when the northern section of the ocean was swept by one storm of hurricane force after another. Both series of gales were noticeable for the extreme deepness of the LOWS. The observer, Mr. P. W. Nelson of the American S. S. *Westpool*, Capt. L. F. Thompson, from Bremen to Boston, reports as follows:

> At 8:15 p. m. (ship's time) on December 4 the following was received from the American S. S. *Balsam*: While in 52° 07' N., 18° 41' W., wind SSE., 10, barometer 27.40 inches. Our position and barometer at same time, 50° 47' N., 16° 38' W., wind NW., 12, barometer 27.46 inches (lowest reading). Both readings corrected.

Both of these vessels are equipped with aneroid barometers, recently compared. While the corrections to be applied at such abnormally low readings may differ somewhat from those obtained at near normal pressure, the close agreement of the two instruments indicates that the error is probably not very large.

William Allingham in his "Manual of Marine Meteorology" states that the Royal Mail steamer *Tarifa* on February 5, 1870, while in 51° N., 24° W., reported a barometer reading of 27.33 inches, which was the lowest ever recorded in this region. As the reliability of the reading of the *Tarifa's* barometer is not known, these of the *Westpool* and *Balsam* can be assumed to be not far from the record.

As shown in the table of storms a number of vessels reported readings below 28 inches in the first decade and two vessels so reported in the last. Due to the duration and severity of the first series of gales the powerful German liner *Bremen* was delayed three days on her westward voyage, arriving in New York on the 13th. Numerous press reports give an idea of the conditions during this period, and also refer to the large number of casualties, which were especially numerous along the British coast.

The low average pressure for the month in this region is shown by the unusually large negative departures at the three land stations on the British Isles, as given in Table 1, although a period of high pressure occurred from the 15th to 19th, the barometric readings at London ranging from 30.43 to 30.72 inches.

It is interesting to note that while these extreme cyclonic conditions existed over the North Atlantic, equally extreme anticyclonic conditions prevailed over the northwestern United States and Alaska, where readings of 31 inches and over were recorded at a number of stations.

Charts VIII to XIII cover the period from the 1st to 6th, inclusive, and not only give an idea of the conditions in the steamer lanes, but also show the "norther" in the Gulf of Mexico that prevailed from the 2d to 4th.

As is generally the case in an unusually stormy month, fog was comparatively rare over the steamer lanes, being

eported on not more than one day in any 5-degree square between the fifteenth and forty-fifth meridians. Fog was reported on from 2 to 3 days between the French coast and fifteenth meridian; on from 3 to 6 days over the Grand Banks; on 10 days along the American coast between New York and Hatteras, while it was unusually prevalent in the Gulf of Mexico, where it was observed on from 4 to 8 days.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, December, 1929*

Stations	Average pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.25	(1)	29.88	30th	28.50	1st.
Belle Isle, Newfoundland	29.74	[2] +0.04	30.34	20th	29.02	25th.
Halifax, Nova Scotia	29.99	[3] +0.04	30.62	13th	28.68	30th.
Nantucket	30.03	[3] +0.01	30.42	23d	29.54	31st.
Hatteras	30.12	[3] 0.00	30.44	1st	29.62	19th.
Key West	30.10	[3] +0.01	30.30	21st	29.86	18th.
New Orleans	30.22	[3] +0.07	30.48	4th [4]	29.66	18th.
Cape Gracias, Nicaragua	29.92	[2] −0.06	29.98	26th	29.84	18th.
Turks Island	30.12	[2] +0.09	30.20	21st	29.92	26th.
Bermuda	30.21	[3] +0.09	30.44	13th	29.92	4th.[4]
Horta, Azores	30.22	[2] +0.11	30.66	31st	29.80	4th.
Lerwick, Shetland Islands	29.28	[2] −0.44	30.45	17th	28.26	29th.
Valencia, Ireland	29.52	[2] −0.42	30.69	16th	28.41	5th.
London	29.72	[2] −0.30	30.72	17th	28.99	5th.

[1] No normal available.
[2] From normals shown on Hydrographic Office Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[3] From normals based on 8 a. m. observations.
[4] And on other date or dates.

On the 7th the conditions over the steamer lanes did not differ materially from those of the 6th as shown on Chart XIII, as winds of hurricane force accompanied by hail and snow prevailed between the twentieth and fortieth meridians. On the 8th the storm area extended from the thirtieth meridian to the British coast, while by the 9th and 10th, it had contracted somewhat in extent, although heavy weather continued along the coast until the 12th. On the 13th, with the exception of a few reports of winds of force 7 from land stations on the British Isles, moderate weather was the rule over the ocean as a whole.

On the 14th southerly winds of force 7 to 10 were reported between the fortieth parallel and Cape Sable, while over the remainder of the ocean moderate conditions prevailed and continued through the 17th.

On the 18th a LOW moderate in intensity and extent was central near 50° N., 33° W. This was evidently a forerunner of the series of disturbances that continued over different sections of the steamer lanes until near the end of the month, the storm area varying considerably in extent from day to day.

On the 19th a norther prevailed over the western sections of the Gulf of Mexico and the station at Vera Cruz reported at the morning observation, wind NNW., 10, barometer 30.10 inches, maximum velocity of wind 76 miles an hour.

From the 19th to 21st most of the heavy weather was confined to the eastern section of the ocean, although on the 20th a southwest wind, force 9, was reported by a vessel near Hatteras. From the 22d to 25th, however, westerly to northwesterly gales covered the major part of the steamer lanes, the storm area reaching its greatest dimension on the 25th, when it extended from the sixtieth meridian to the coast of Europe, north of the fortieth parallel. On the 26th and 27th the force of the wind as well as the area covered had diminished somewhat, the latter then extending from the thirty-fifth to fiftieth parallels and twentieth to fiftieth meridians, while on the 26th winds of force 10 were also reported between the Bermudas and Nantucket.

On the 28th and 29th the region between the thirtieth meridian and the coast of Europe was swept by southwesterly to westerly gales, the weather being especially severe on the coast on the latter day. On the 30th heavy weather continued off the coast of France and there was also a disturbance between the Bermudas and Nova Scotia, one vessel about 150 miles south of Sable Island reporting a southwesterly wind, force 12.

OCEAN GALES AND STORMS, DECEMBER, 1929

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Kerhonkson, Am. S. S.	New York	Glasgow	55 00 N.	21 00 W.	Nov. 30	7 p. Dec. 1	Dec. 3	27.83	W	WSW., 11	SW	WSW., 11	SSE.-S-SSW.
Winnebago, Br. S. S.	do	Avonmouth	47 09 N.	32 50 W.	Dec. 1	10 p., 2	3	28.89	NNW	NW., 10	NW	—, 10	W-NW.
West Hobomac, Am. S. S.	New Orleans	Glasgow	51 30 N.	8 35 W.	2	4 a, 2	2	29.00	WSW	SW, 11	W	SW., 11	SSW-W.
San Macedonio, Br. S. S.	Tampico	Rio de Janeiro.	22 21 N.	93 50 W.	2	Noon, 2	3	29.95	NW	N., 7	N	N., 9	Steady.
Hoxie, Am. S. S.	New York	Glasgow	45 35 N.	40 00 W.	2	6 p.	3	28.64	NNW	SW., 11	NW	SW., 12	
Manchester Spinner, Br. S. S.	Halifax	Liverpool	51 14 N.	25 16 W.	4	Noon, 4	5	(1)	SSW	WSW., 11	WNW	WSW., 11	WSW-W-NW.
Westpool, Am. S. S.	Bremen	Boston	51 30 N.	16 01 W.	4	—, 4	11	27.46	SSE	WNW., 12	SW	—, 12	NW-SW.
Reliance, Ger. S. S.	Hamburg	New York	49 54 N.	29 30 W.	4	8 a, 4	7	27.81	NW	WSW., 11	W	—, 12	WSW-NW.
West Eldara, Am. S. S.	New York	Antwerp	48 58 N.	25 44 W.	1	9 a., 4	5	27.85	WNW	W., 12	WNW	—, 12	
Baltic, Br. S. S.	Liverpool	New York	49 37 N.	28 24 W.		8 a., 4	7	27.74		NW., —	NNW	—, 12	SW-NW.
Middleham Castle, Br. S. S.	Galveston	Havre	47 15 N.	14 52 W.	4	4 a., 5	5	28.88	SSW	SSW., 8	SW	SSW., 10	SSW-SW.
France, Fr. S. S.	Havre	New York	49 50 N.	15 16 W.	6	Noon, 6	7	28.21	WNW	WNW., 12	WSW	WNW., 12	
Henri Jasper, Belg. S. S.	New York	Antwerp	49 10 N.	31 00 W.	6	Noon, 7	8	29.19	WSW	WNW., 12	WNW	WNW., 12	steady.
Moerdijk, Du. S. S.	London	Curacao	49 16 N.	4 55 W.	8	—, 8	10	29.31	SW	—, 9	NW	—, 11	
West Gambo, Am. S. S.	New Orleans	Bremen	49 00 N.	8 30 W.	10	9 a, 10	13	29.63	SW	SW., 7	WNW	W., 12	
Grete, Ger. S. S.	Hamburg	Tampa	46 00 N.	16 00 W.	20	1 p, 21	24	29.17	SW	WNW., 10	WNW	WNW., 11	
Natira, Am. S. S.	Boston	Hamburg	43 48 N.	45 00 W.	22	11 a, 22	25	29.15	NW	—, 8	NW	—, 9	
Schoharie, Am. S. S.	Savannah	Liverpool	46 03 N.	40 13 W.	23	—, 23	24	29.18	NW	NW., 10	NW	—, 10	Steady.
River Delaware, Br. S. S.	New York	Gibraltar	39 48 N.	54 50 W.	24	3 p, 24	25	29.64	S	SW., 7	NW	SW., 10	S-SW-NW.
Topa Topa, Am. S. S.	Wilmington, N. C.	Liverpool	51 00 N.	17 00 W.	21	—, 24	25	27.69	W	NW., —	NW	—, 11	E-SE-NW.
Hoxie, Am. S. S.	Avonmouth	Baltimore	46 20 N.	20 35 W.	20	7 a, 24	29	28.66	WSW	WNW., 10	N	WNW., 12	S-WNW-NW.
Boston City, Br. S. S.	Fowey	Boston	49 48 N.	19 15 W.	24	11 a, 24	25	28.03	SE	NW., 12	NW	NW., 12	SE-S-NW.
Jobshaven, Du. S. S.	Rotterdam	New York	41 13 N.	49 20 W.	22	9 a, 25	25	29.59	NW	SW., 11	SW	SW., 11	SW-W.
West Tacook, Am. S. S.	Houston	Havre	37 48 N.	65 59 W.	26	—, 26	26	29.48	ESE	ESE., 3	NW	—, 10	ESE-NNE.
Florida, Dan. S. S.	Newcastle	Portland, Me.	52 00 N.	36 20 W.	24	2 a, 26	26	27.92	N	NW., 11	NNW	NW., 11	SW-NW.

[1] Observer states that at 10.17 a. m., Dec. 4, barometer was below lowest graduation, the hand resting against the thermometer attached to dial. At 1 p. m., Dec. 6, the barometer read 28 inches.

Ocean gales and storms, December, 1929—Continued

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
***NORTH ATLANTIC OCEAN*—Continued**			° ′	° ′				*Inches*					
Sneaton, Br. S. S.	St. Vincent	Cork	22 20 N.	22 56 W.	26	6 p, 26	28	29.96	NE	FSE., 6	E	E, 9	NE-ESE.
Milwaukee, Ger. S. S.	Southampton.	New York	45 52 N.	41 20 W.	27	9 a, 27	27	29.16	SE	NE., 12	WNW	NE., 12	
Dosina, Du. S. S.	Rotterdam	Curacao	46 30 N.	46 30 W.	28	7 p, 28	29	29.46	WSW	SW., 10	W	W., 12	WSW-W.
Lubrafol, Belg. S. S.	Amsterdam	Galveston	45 23 N.	17 18 W.	28	2 p, 28	28	29.33	SW	SW., 10	NW	W., 11	SW-W-NW.
Asia, Dan. M. S.	Rotterdam	Alexandria	49 00 N.	4 20 W.	28	4 a, 29	30	29.26	SW	WSW., —	NW	—, 12	WSW-W.
Milwaukee, Ger. S. S.	Southampton.	New York	42 00 N.	60 10 W.	29	8 a, 30	30	29.07	SE	WSW., 11	WNW	—, 12	WSW-W-WNW.
NORTH PACIFIC OCEAN													
Siberia Maru, Jap. S. S.	Yokohama	Victoria	45 50 N.	163 30 E.	1	4 a., 4	4	29.41	NNE	NNW., 8	NNW	NNW., 9	Steady.
Charles H. Cramp, Am. S. S.	Balboa	San Diego	12 54 N.	90 46 W.	2	Noon, 2	3	29.90	N	N., 7	NW	NW., 8	Steady.
Manoa, Am. S. S.	San Francisco	Honolulu	26 12 N.	149 26 W.	2	11 a., 2	3	29.69	W	NNW., 7	N	NNW., 8	W.-NNW.
Pres. Van Buren, Am. S. S.	Honolulu	Kobe	33 50 N.	149 34 E.	3	2 a., 3	3	29.62	NE	NNE—	NNE	NNE., 10	Steady.
Erviken, Nor. S. S.	Hong Kong	San Francisco	26 31 N.	120 05 E.	3	4 a., 3	4	30.06	NE	N., 6	NE	NE., 8	N.-NE.
William Penn, Am. M. S.	San Pedro	Balboa	14 25 N.	95 23 W.	3	4 p., 3	4	29.87	NNE	NNW., 10	NNW	NNE., 10	NNE.-NNW.
Akagisan Maru, Jap. M. S.	Portland	Yokohama	54 24 N.	175 00 W.	3	4 a., 4	4	29.43	SSE	SSE., 9	WNW	SSE., 11	SSE.-WNW.
Tsuyama Maru, Jap. S. S.	Yokohama	San Francisco	40 17 N.	151 34 W.	3	Mdt., 4	6	29.35	NNE	SE., 9		SE., 9	SE.-S.
Athelmere, Br. S. S.	San Pedro	Yokohama	33 55 N.	174 50 E.	4	4 a., 5	5	29.86	SSE	SW., —	WNW	SSE., 12	
Tejon, Am. S. S.	do	Balboa	15 35 N.	96 20 W.	4	7 p., 4	5	29.95	E	E., 7	NW	N., 8	
Tahchee, Br. S. S.	do	Shanghai	32 54 N.	153 16 W.	5	4 a., 5	6	29.54	WSW	WSW., 7	WSW	W., 10	WSW.-W.
Pennsylvania, Am. S. S.	Columbia River.	Yokohama	42 36 N.	154 17 E.	5	Noon, 5	6	29.16	ESE	NW., 9	NNW	NW., 10	S.-NW.
Olympia, Am. S. S.	Otaru	San Francisco	44 00 N.	155 00 W.	5	10 a., 5	6	29.76	NE	NE., —	NE	NE., 9	ENE.-NE.
Do	do	do	44 00 N.	146 00 W.	8	6 a., 8	9	29.36	NE	NE., —	NNW	NE., 9	NE.-N.
Pres. Madison, Am. S. S.	Seattle	Yokohama	49 26 N.	176 15 E.	5	9 p., 6	10	29.23	SSW	ESE., 2	WNW	NW., 10	ESE.-NW.
Oregon, Am. S. S.	Portland	Shanghai	50 39 N.	137 52 W.	9	11 a., 9	11	29.67	NNE	NNE., 9	NNE	NNE., 9	
Admiral Peoples, Am. S. S.	San Francisco	Portland	41 21 N.	124 36 W.	13	2 p., 13	14	29.79	SE	SE., 8	SSW	SE., 8	
Pennsylvanian, Am. S. S.	New York	Los Angeles	14 30 N.	95 32 W.	19	2 p., 19	19	29.81	N	NNE., 9		NNE., 10	N.-NNE.
Atlanta City, Am. S. S.	Honolulu	Yokohama	21 45 N.	161 35 W.	14	4 p., 14	17	29.76	S	S., 6	NNE	NW., 9	S.-SSW.
Oregon, Am. S. S.	Portland	Shanghai	49 55 N.	172 45 E.	20	—, 20	21	29.57	ESE	ESE., 7	W	W., 11	
Pres. Grant, Am. S. S.	Yokohama	Victoria	40 07 N.	150 55 E.	21	10 a., 21	21	28.62	E	NNW., 9	NW	NNW., 12	SW.-NNW.
Do	do	do	46 22 N.	168 48 E.	23	8 p., 23	24	29.27	SSE	SW., 8	W	—, 10	SSE.-W.
Emp. of Prussia, Br. S. S.	Victoria	Honolulu	46 09 N.	129 25 W.	22	Noon, 22	22	29.67	SW	SW., 8	W	SW., 8	SW.-W.
Erviken, Nor. S. S.	Miike	San Francisco	45 55 N.	166 50 W.	21			29.19	WSW	WSW., 2	W	WNW., 10	WSW.-W.
Diana Dollar, Am. S. S.	Yokohama	San Pedro	45 34 N.	153 40 W.	22	12 p., 22	23	29.42	SSE	SW., 9	W	SW., 9	SSE.-SSW.
Atlanta Sun, Am. S. S.	Philadelphia	do	13 45 N.	94 03 W.	23	Noon, 23	24	29.99	N	N., —	NNW	N., 10	N.-NNE.
Pres. Jackson, Am. S. S.	Victoria	Yokohama	39 58 N.	147 41 E.	25	Noon, 25	26	29.57	W	WNW., 8	WNW	NW., 10	
Oregon, Am. S. S.	Portland	Shanghai	44 58 N.	152 30 E.	25	9 p., 25	26	28.96	NW	N., 12	NW	N., 12	NW.-N.
Siberia Maru, Jap. S. S.	Victoria	Yokohama	51 53 N.	150 32 W.	24	8 p., 27	28	29.24	SE	SW., 7	W	SSW., 10	SSW.-WSW.
Havre Maru, Jap. S. S.	Miike	Coos Bay	49 17 N.	144 39 W.	26	4 a., 27	27	29.50	S	SW., 10	SSW	SW., 10	S.-SW.
Carlier, Belg. S. S.	Muroran	Vancouver	41 24 N.	154 16 E.	26	—, 26	27		NW	NW., 8	NW	NW., 9	3 pts.
Oregon, Am. S. S.	Portland	Shanghai	42 55 N.	148 06 E.	27	2 p., 27	27	29.53	W	W., 10	WNW	W., 10	W.-NW.
Atlantic City, Am. S. S.	Honolulu	Yokohama	33 00 N.	142 00 E.	27	4 a., 28	29	29.99	SW	SW., 6	NW	NE., 10	S.-SW.-NW.
Pres. McKinley, Am. S. S.	Victoria	do	50 20 N.	131 50 W.	29	Mdt., 29	30	29.44	SSW	SW., 10	W	SW., 10	SSW.-W.
J. A. Moffett, Am. S. S.	La Union	San Pedro	15 45 N.	95 00 W.	28	4 a., 29	29	29.94	NNW	NW., 8	NNE	NW., 8	
Wilhelmina, Am. S. S.	Portland	Honolulu	29 40 N.	148 40 W.	28	4 p., 31	31	29.82	S	S., 4	SE	ENE., 9	S.-N.
Nevada, Am. S. S.	Manila	San Francisco	34 50 N.	159 45 E.	31	11 p., 31	Jan. 1	29.28	SSE	SSE., 9	NNW	SSW., 10	
SOUTH PACIFIC OCEAN													
Canadian Leader, Br. S. S.	Sydney	Panama	34 19 S.	154 17 W.	15	5 a., 16	Dec. 15	28.98	N	S., 9	WSW	N., 9	N.-W.-S.
SOUTH ATLANTIC OCEAN													
Capillo, Am. S. S.	Montevideo	Jacksonville	16 25 S.	36 45 W.	2	10 a., 2	2	29.83	SE	SE., 9		SE., 9	SE.-SW.
Gustav Schindler, Ger. S. S.	Durban	Dakar	35 10 S.	20 26 E.	2	8 p., 2	3	29.54	WSW	WSW., 8	W	W., 10	WSW.-NW.

NORTH PACIFIC OCEAN [1]

By WILLIS E. HURD

During the greater part of the early half of December, 1929, high atmospheric pressure overlay most of the Aleutian region, and it was not until well into the latter half of the month that deep cyclonic conditions prevailed over northeastern waters—28.76 inches at Dutch Harbor on the 27th and 28.82 at Kodiak on the 28th being the minimum readings at land stations. The average for the month showed a shallow depression of 29.75 inches extending westward from Kodiak to the central Aleutians. at least, and covering the eastern part of the Bering Sea,

Cyclonic conditions prevailed in central latitudes from the 8th to the 17th, after which dates the California-Pacific anticyclone gradually spread out and influenced the weather along a goodly portion of the middle steamship routes. In the waters of the Far East south of the latitude of Japan, strong and extensive high-pressure areas alternated frequently with shallow LOWS from China.

Barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean, are given in the following table:

[1] Cf. Bowie, E. H. The long dry season of 1929 in the Far West Mo. Wea. Rev. 57: 449-451.—EDITOR.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, December, 1929*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1] [2]	30.00		30.62	19th	29.20	28th.
Dutch Harbor [1]	29.75	+0.17	30.36	5th	28.76	27th.
St. Paul [1]	29.75	+0.14	30.44	5th	29.04	24th.[3]
Kodiak [1]	29.75	+0.17	30.42	6th	28.82	28th.
Midway Island [1] [4]	30.11	+0.07	30.34	1st [3]	29.88	5th.
Honolulu [5]	29.94	−0.08	30.07	6th	29.74	15th.
Juneau [5]	29.89	+0.10	30.35	17th	29.06	26th.
Tatoosh Island [5] [6]	29.97	0.00	30.44	27th	29.29	10th.
San Francisco [5] [6]	30.12	+0.01	30.34	21st	29.84	11th.
San Diego [5] [6]	30.04	0.00	30.29	21st	29.76	19th.

[1] P. m. observations only.
[2] For 28 days.
[3] And on other dates.
[4] For 30 days.
[5] A. m. and p. m. observations.
[6] Corrected to 24-hour mean.

December as a whole was a somewhat stormier month than November over most of the upper half of the ocean, although the number of the more violent gales was less. High winds this month were more widespread as to area and days of occurrence and were reported from some locality or other on every day except the 12th. The greatest number of days with gales reported from any 5° square was 8, occurring east of Japan. Data at hand show that steamships encountered full storm to hurricane velocities on four days; on the 4th, in the lower part of the Bering Sea and also a few hundred miles northwest of Midway Island; on the 20th, south of the western Aleutians; and on the 21st and 25th, east of northern Japan. In November there were seven days with wind forces of 11 to 12 on the ocean, latest reports for the month showing that violent gales, not mentioned in the previous review of North Pacific weather, occurred east and northeast of Japan on the 23d, 24th, and 27th.

During the current month wind forces of 8 to 10 were common along the whole length of the northern and much of the middle routes. From the 2d to the 6th a cyclone that prevailed between the Hawaiian Islands and California occasioned much rough weather, with fresh to whole gales, and anticyclonic gales occurred in the same region on the 30th and 31st. On the 13th, 14th, 22d, 24th, and 25th gales were encountered along the Washington, Oregon, and northern California coasts. The maximum wind velocity at Tatoosh Island was at the rate of 57 miles an hour—force 10—from the east on the 13th.

To the westward of the coast region as far as the one hundred and eightieth meridian, north of the parallel of 40°, while frequent gales blew early in the month, the greatest number occurred in the last decade during the days when the Aleutian cyclone was most active. West of the central meridian the frequent gales were due largely to the presence of a fairly permanent cyclonic area—the westernmost extension of the Aleutian Low—south of Kamchatka, and to the activity of a number of cyclones which entered the ocean from Asia. Off the coast of China gales, usually of moderate force but sometimes becoming fresh, were of the northeast monsoon type. These were apparently of greatest severity on the 3d and 4th, when a powerful anticyclone pushed upon the China and Eastern Seas.

The Gulf of Tehuantepec was the scene this month of frequent strong northers. Gales were reported by seamen as occurring here on at least 12 days, on four of which, the 3d, 19th, 22d, and 23d, they attained to whole gale force. Several of these blew over a wide area of sea to the southward, but ceased rather abruptly to the westward of the gulf, as witness the instance of the British motorship *Loch Goil*, which, in lat. 16° N., long. 99° W., on the 19th was experiencing calms and light airs, while a violent Tehuantepecer was blowing south of the isthmus. At Salina Cruz maximum wind velocities from the north, in miles per hour, occurred as follows: On the 3d, 64 miles; 4th and 26th, 56 miles; 29th, 60 miles, these constituting whole gales to storm winds at the head of the bay.

The prevailing wind direction at Honolulu was northeast, whereas in December it is usually east, and the maximum wind velocity was at the rate of 28 miles an hour from the northeast on the 30th.

Over the northwestern part of the ocean scattered fog showed an increase from two days of occurrence in November to five days in December. It was most widespread in area on the 9th, 10th, and 19th. Occasional fog was met with thence eastward to American waters. Along the American coast it was reported on seven days in the vicinity of Puget Sound, on 13 days outside of San Francisco Harbor, and on eight days outside of San Diego. It decreased southward, but occurred on the 11th and 12th in the Gulf of Tehuantepec. Here the American steamship *Corinto* encountered it with a west-southwesterly wind, immediately following a strong norther from west-northwest on the 11th.

TYPHOONS AND DEPRESSIONS IN NOVEMBER, 1929

By Rev. José Coronas, S. J.

Weather Bureau, Manila, P. I.

One Philippine and China Sea typhoon and one Pacific typhoon.—There were only two well-developed typhoons noticed over the Far East during the month of November, one of them having traversed the Philippines through the Visayan Islands and the Sulu Sea on the 10th and 11th.

This Philippine typhoon was probably formed on the 8th in very low latitude to the southwest of Pelew Islands near 132° longitude E. and 5° latitude N. It moved northwestward on the 8th and inclined to WNW. on the 9th, reaching the Philippines near to the north of Surigao during the night of the 9th to 10th. In the morning of the 10th it moved NNW. for a few hours, and then it took a westward direction in the afternoon of the same day. This west direction was kept until the 12th when it began to move again to WNW. in the China Sea.

While traversing the Visayan Islands, this typhoon appeared to be only a shallow depression of little importance; but it began to develop more in the Sulu Sea and became a much developed and severe typhoon in the China Sea. The steamer *Calchas* passed through its center at 3:30 p. m. of November 14 in 112° 07′ longitude E. and 13° 57′ latitude N. The barometric minimum recorded at that time was as low as 28.38 inches (720.84 mm.), the winds blowing from ENE. force 9 before the minimum and from SW. force 9 to 10 after the minimum. The captain of the steamer describes thus the passing of the center:

> In the central area, we noticed many land birds including a wild duck. The sun shone clearly for a period of about 20 minutes. The wind was light and variable, and the sea was very rough and confused (pyramidal).

The approximate positions of the center at 6 a. m. of November 8 to 15 were as follows:

November 8, 6 a. m., 132° 15′ longitude E. 5° 25′ latitude N.
November 9, 6 a. m., 129° 45′ longitude E., 7° 45′ latitude N.
November 10, 6 a. m., 124° 25′ longitude E., 10° 30′ latitude N.

November 11, 6 a. m., 121° 15′ longitude E., 11° 25′ latitude N.
November 12, 6 a. m., 118° 10′ longitude E., 11° 35′ latitude N.
November 13, 6 a. m., 115° 50′ longitude E., 12° 20′ latitude N.
November 14, 6 a. m., 113° 40′ longitude E., 13° 10′ latitude N.
November 15, 6 a. m., 110° 40′ longitude E., 14° 20′ latitude N.

The other Pacific typhoon was shown in our weather maps of the 20th as forming to the south of Guam not far from 145° longitude E. and 9° latitude N. It moved northwestward until the 23d when it recurved to NNE. to the west of the southern part of the Ladrone Islands. The steamer *Ramapo* was involved in this typhoon near to the west of the Ladrone Islands with a falling barometer and strong winds and squalls from the southeast quadrant.

The approximate positions of the center of this typhoon at 6 a. m. of November 21 to 27 were:

November 21, 6 a. m., 144° 10′ longitude E., 9° 30′ latitude N.
November 22, 6 a. m., 141° 00′ longitude E., 11° 50′ latitude N.
November 23, 6 a. m., 139° 10′ longitude E., 14° 30′ latitude N.
November 24, 6 a. m., 140° 20′ longitude E., 17° 10′ latitude N.
November 25, 6 a. m., 140° 55′ longitude E., 18° 00′ latitude N.
November 26, 6 a. m., 142° 50′ longitude E., 21° 05′ latitude N.
November 27, 6 a. m., 149° 30′ longitude E., 28° 25′ latitude N.

THE FIJI HURRICANE OF DECEMBER, 1929

By WILLIS E. HURD

From the 7th to the 14th of December, 1929, a hurricane raged over and in the general vicinity of the Fiji Islands. Our present knowledge of this intense storm rests largely upon the facts contained in a series of reports submitted to the Weather Bureau by Mr. J. H. Berendsen, second officer of the American steamship *Golden Rod*, en route from Sydney, New South Wales, toward the Hawaiian Islands and San Francisco, via the Fijis. In addition to his own experiences, Mr. Berendsen kindly furnished radio messages received from other vessels and from Fijian and other land stations, including copies of hurricane warnings and advices transmitted from Suva.

The only additional report of the storm received was that of the British steamship *Waitemata*, Captain Jannay, Observer McCarry, Westport, New Zealand, to Vancouver. This vessel at midnight of the 10th, while at some distance south of the cyclone center, ran into whole southeasterly gales which persisted with incessant rain until 3 p. m. of the 11th when, to use the words of the observer, "the wind shifted to NE., reaching hurricane force, the ship being hove to in lat. 21° 45′ S., long. 178° W., lowest barometer 29.26. About 2 a. m. of the 12th the wind shifted to ENE. and remained there throughout the day, the gale gradually decreasing in force."

The *Golden Rod* entered the extreme forward rim of the storm zone—which was many hundreds of miles in extent—with a southeasterly gale of force 7, near lat. 22° 23′ S., long. 172° 39′ E., on the afternoon of the 10th. Thence, though at no time close to the actual hurricane center, she had mostly rough seas and strong winds to strong or whole gales until she entered harbor on the 14th, at which time the storm had passed her and was central approximately 300 to 350 miles to the southward and was moving in the general direction of Norfolk Island.

The initial appearance of the storm, as gathered from the reports of the *Golden Rod*, seems to have been near the tenth parallel of south latitude to the southeastward of the Ellice Islands, although a radio message of Monday, December 8, leads one to the suspicion that it may have originated a few days earlier considerably to the northeastward of the Ellice Group. Quoting this message:

The *Norwich City* went on reef and broke up last week at Garden Island in Phoenix Group. Eleven persons were drowned. The steamer *Lincoln Ellsworth* has 12 survivors aboard; the rest were picked up by some British steamer.

During its early days the cyclone was evidently traveling in a southwesterly direction, and on the 9th lay north or somewhat to the northwest of the Fijis. A report from the Norwegian steamship *Tyr*, at 8 p. m. of the 9th in lat. 16° 56′ S., long. 176° 05′ E., gave a southeast wind of force 10 and an atmospheric pressure of 29.33 inches. It was apparent on this date that the storm was curving into southward, and a report from Suva showed a barometer depressed to 29.56 inches, wind ESE., force 6.

On the 10th Suva sent out a report of a pressure of 29.39 inches, wind SE. by E., force 7 to 8, rainy and squally weather. At 8 a. m. the steamship *Pinna*, anchored in Nandi Bay, outside Lautoka, Fiji, reported a barometer of 29.18, wind SSE., 8. The storm had now recurved into southeast and was headed directly upon the Fiji Group.

At noon of the 11th the hurricane center was slightly north of Suva, where the barometer read 29.22, with a fresh southeast gale, and was moving upon Savu Savu, where at 12:40 p. m. a hurricane wind from northeast was raging, with barometer at 28.48.

On the 12th the hurricane, after passing Suva to the eastward, slowly recurved from southeast into south over the Koro Sea. Fresh to strong shifting gales were yet blowing at Suva, but the winds were diminishing rapidly at Savu Savu. At least one important line of communication—the land line to Levuka—was reported interrupted.

At 8:30 p. m. of the 13th Suva reported the storm as well to the southward, now apparently heading south-southwest. The Danish motor ship *Jane Maersk*, in 23° S., 178° E., at 8 p. m., with a barometer of 29.33, rising, was experiencing a south wind of force 11, which attests to the violence of the cyclone at this time.

THREE TROPICAL CYCLONES OF THE SOUTH PACIFIC OCEAN, 1927-28

By WILLIS E. HURD

His Excellency the Governor of New Caledonia, at Noumea, in a recent communication to the Hydrographic Office, which was forwarded to the Weather Bureau, inclosed data relative to three tropical disturbances in the South Pacific Ocean which occurred during the period December, 1927, to May, 1928.

The earliest was experienced at the beginning as a fresh northeast gale, pressure 29.33 inches, at Port Vila, Elate Island, in the New Hebrides Group, on the afternoon of December 29. Fresh to strong north gales occurred during the early hours of the 30th, with barometer dropping to a minimum of 29.13. At 10 a. m. the wind went into northwest, force 10, with rising pressure, as the cyclone passed the island to the westward, and after 2 p. m. the force lessened. The storm, which was encountered with moderate severity by the steamships *Makambo* and *Cassiopec*, proceeded in a south-southeasterly direction across the Loyalty Group midway between the New Hebrides and New Caledonia, the center passing a short distance east of Noumea at 2 a. m. of the 31st. It crossed Walpole Island at 10 a. m. and continued on the southward of the Fijis during January 1.

The cyclone of February 8–9, 1928, was of considerable violence over some portions of the New Hebrides Group, in particular devastating the south end of Santo Island and the northern part of the close-lying island of Aore, where it badly damaged buildings and broke down or uprooted the palm trees. At Lunganville, on the southeast of Santo, the barometer dropped from 29.84, at 7 p. m., to 28.78 inches, at 9 p. m. of the 8th, the wind at both hours being from east-southeast. The cyclone approached from the eastward, the center crossing five islands of the group, then going in a southwesterly

direction toward New Caledonia. It appears to have been of no great width, since at Port Vila, New Hebrides, the barometer remained in the neighborhood of 760 millimeters (29.92 inches).

The third disturbance was that of May 14–15 over and in the vicinity of the Society Islands. It passed slightly east of Tahiti, the largest island of the group and, proceeding south then southeast, became lost to observation. The steamship *La Bretagne* entered the storm area at some distance south of Tahiti about 1 p. m. of the 14th with increasing southeast wind and lowering barometer. At midnight the wind shifted to south, force 9, pressure 29.00 inches, and at 3:30 a. m. of the 15th the vessel passed through the eye of the cyclone. At this time a few stars were visible. From 10 p. m. of the 14th until 4 or 5 a. m. of the 15th the barometer oscillated rapidly between 28.98 and 29.13 inches. At 7 a. m. the south wind decreased in force, and at 1 p. m. changed to southwest with squalls of lessened violence, pressure rising in a few hours to 29.96 inches.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, December, 1929

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	45.6	−1.7	2 stations	81	[2] 9	St. Bernard	−4	24	3.72	−1.13	Robertsdale	6.57	2 stations	2.15
Arizona	47.5	+3.7	Supai	85	14	Payson	−3	22	0.14	−1.25	2 stations	0 91	66 stations	0.00
Arkansas	44.4	+1.9	Hope	82	12	Dutton	−5	20	3.84	−0.21	El Dorado	5.88	Jonesboro	1.51
California	49.7	+4.7	Santa Ana	90	29	Portola	4	31	4.61	+0.37	Kennett	35.84	57 stations	0.00
Colorado	28.6	+3.3	2 stations	75	[2] 10	Dillon	−28	22	0.26	−0.83	Silver Lake	2.03	11 stations	0.00
Florida	59.1	−0.6	Venus	90	8	Garniers	14	20	2.84	−0.02	Miami	9.03	La Belle	0.79
Georgia	46.7	−0.9	Millen	84	16	Tallapoosa	7	24	3.70	−0.56	Fargo	5.46	Atlanta	1.77
Idaho	32.6	+6.8	Hazelton	75	13	Felt	−12	21	3.07	+0.83	Roland	11.25	Sugar	0.23
Illinois	30.8	+0.3	Sparta	74	12	Danville	−11	3	2.32	+0.08	Carbondale	5.57	Morrison	0.46
Indiana	31.2	−0.9	Columbus	71	31	Marengo	−15	3	3.93	+1.03	Veedersburg	6.85	Plymouth	1.25
Iowa	24.8	+0.7	Guthrie Center	67	30	2 stations	−16	19	0.39	−0.75	Burlington	1.21	Glenwood	0.03
Kansas	34.7	+3.1	Richfield	79	10	Oberlin	−6	20	0.19	−0.75	Pittsburg	0.85	12 sations	0.00
Kentucky	39.1	+1.6	Greenville	76	[2] 16	Eubank	−15	3	2.73	−1.30	Grayson	4.56	Pikeville	1.38
Louisiana	50.7	−1.6	New Orleans (No. 2)	83	13	Plain Dealing	−1	23	4.27	−0.98	Abbeville	8.06	Burrwood	1.46
Maryland-Delaware	36.9	+1.8	Salisbury, Md	75	15	2 stations	−6	1	2.45	−0.86	Wilmington, Del	3.84	Chewsville, Md	1.21
Michigan	23.6	−1.2	L'Anse	51	30	2 stations	−21	[2] 1	2.31	+0.16	Trowbridge	5.10	Seney	0.54
Minnesota	13.7	−0.8	2 stations	51	[2] 4	Red Lake Falls	−38	18	0.58	−0.18	Fosston	2.25	Worthington	0.03
Mississippi	47.0	−0.7	7 stations	81	[2] 9	Duck Hill	−4	23	3.66	−1.91	Rosedale	5.81	Water Valley	1.45
Missouri	35.2	+1.3	Rolla	76	11	Jackson	−9	3	1.66	−0.41	Poplar Bluff	5.46	Oregon	0.15
Montana	22.9	+0.7	Chinook	73	29	Glasgow	−47	18	1.82	+1.05	Heron	8.36	Ekalaka	0.12
Nebraska	29.0	+3.2	Sidney	80	14	Butte	−18	18	0.08	−0.68	Tekamah	0.78	24 stations	0.00
Nevada	39.5	+8.1	Las Vegas	78	29	San Jacinto	−6	13	0.75	−0.17	Marlette Lake	5.99	9 stations	0.00
New England	25.5	−1.1	Nantucket, Mass	58	18	2 stations	−25	12	3.66	+0.28	Kingston, R. I	6.01	Bar Harbor, Me	1.21
New Jersey	33.8	+0.9	2 stations	68	15	do	2	12	3.01	−1.08	Woodcliff Lake	4.34	Asbury Park	1.00
New Mexico	36.1	+2.4	Richland	82	31	Elizabethtown	−28	21	0.12	−0.63	Cloudcroft	0.62	9 stations	0.00
New York	26.6	0.0	Oneonta	63	19	Indian Lake	−28	12	3.71	+0.73	High Market	6.93	Lauterbrunnen	1.71
North Carolina	43.3	+0.9	2 stations	79	15	Brevard	−7	24	3.06	−0.95	Hatteras	5.87	Marshall	1.15
North Dakota	12.5	−0.5	Park River	59	30	Dunn Center	−38	18	0.81	+0.27	Cando	2.10	Amenia	0.10
Ohio	31.8	+0.6	Ironton	71	13	Wauseon	−4	20	3.41	+0.58	Marion	5.42	Portsmouth	1.86
Oklahoma	42.8	+3.6	5 stations	80	[2] 10	2 stations	−7	19	0.90	−0.76	Antlers	5.56	7 stations	0.00
Oregon	39.7	+5.3	2 stations	72	[2] 9	Danner	−6	3	8.13	+2.95	Valsetz	23.18	Andrews	0.35
Pennsylvania	32.2	+1.1	Hanover	70	14	Brookville	−9	1	2.77	−0.46	Clearfield	4.95	Newell	1.21
South Carolina	46.0	−0.5	Summerville	81	16	Caesars Head	5	20	4.14	+0.61	Caesars Head	6.24	Winthrop College	2.39
South Dakota	20.9	+1.3	2 stations	64	14	Strool	−30	18	0.24	−0.40	Hardy Ranger Station.	1.09	2 stations	0.00
Tennessee	41.2	+0.7	Moscow	75	[2] 14	2 stations	−5	3	3.11	−1.42	Dresden	4.87	Altamont	1.40
Texas	49.8	0.0	2 stations	89	[2] 9	Junction	−11	22	1.69	−0.47	Nacogdoches	7.39	9 stations	0.00
Utah	33.4	+6.7	Springdale	71	[2] 15	Woodruff	−21	21	0.38	−0.80	Silver Lake	1.73	8 stations	0.00
Virginia	40.0	+2.0	Pedlar Dam	76	[2] 15	Burkes Garden	−8	1	2.11	−1.08	Randolph	3.30	Runnymede	0.90
Washington	35.5	+3.2	Lowden	67	9	Stockdill Ranch	−2	20	6.11	+0.42	Big Four	29.13	Ephrata	0.59
West Virginia	36.6	+3.1	Moorefield	73	14	Pickens	−13	1	2.51	−0.79	Bruceton Mills	5.59	Upper Tract	0.59
Wisconsin	20.3	+0.3	High Falls	59	30	2 stations	−25	[2] 19	0.73	−0.60	Brule Island	2.50	Amery	0.11
Wyoming	26.3	+5.9	Dull Center (near)	69	13	Riverside	−28	21	0.49	−0.27	Snake River	2.86	2 stations	0.00
Alaska (Nov.)	22.4	+7.3	2 stations	60	[2] 1	Barrow	−36	28	4.18	+1.48	Chignik	27.99	Barrow	0.10
Hawaii	69.2	−0.7	Kaanapali	89	[2] 12	Kula Sanitarium	41	27	15.92	+5.53	Eke	52.32	Waiawa	0.00
Porto Rico	74.4	−0.5	San German	93	28	Guineo Reservoir	47	26	3.68	−1.17	Rio Grande	15.99	Coamo	0.26

[1] For description of tables and charts, see REVIEW Jan. 1929, p. 36.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1929*

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind										
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with .01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
New England							28.8	-0.6										78	3.79	+0.4										7.0		
Eastport	76	67	85	29.91	30.00	+0.02	24.2	-2.1	45	20	31	2	23	18	28	23	19	77	3.57	-0.2	17	8,498	w.	36	e.	24	4	6	21	8.0	17.6	4.5
Greenville, Me.	1,070	6		28.80	30.02		15.6		37	14	22	-10	11	9	31				3.41		16	5,729	nw.	45		9	5	8	18		28.5	
Portland, Me.	103	82	117	29.92	30.05	+.02	25.6	-2.0	42	14	32	3	23	20	22	23	19	77	4.89	+0.9	13	5,751	n.	23	n.	15	10	5	16	6.4	21.2	5.1
Concord	289	70	79	29.68	30.01	-.05	25.5	-1.3	45	14	32	-2	12	19	24				2.17	-1.0	9	3,300	nw.	21	n.w.	31	9	7	15	6.2	10.6	4.7
Burlington	403	11	48	29.55	30.02	-.03	20.6	-3.8	41	27	28	-11	12	14	28				3.47	+1.6	21	6,556	s.	36	s.	27	2	4	25	8.6	30.6	7.0
Northfield	876	12	60		30.05	.00	19.8	-0.6	44	27	29	-20	12	10	37			84	2.53	0.0	14	3,841	n.	19	ne.	24	1	6	24	8.4	21.6	8.4
Boston	125	106	165	29.90	30.04	-.01	32.6	+0.1	52	14	39	7	12	26	26	29	24	71	4.43	+1.0	13	5,312	w.	22	nw.	31	7	11	13	6.8	10.6	T.
Nantucket	12	14	90	30.01	30.02	-.03	37.3	+1.5	58	18	43	23	11	32	22	34	32	84	4.13	+0.4	14	10,365	w.	42	e.	23	4	8	19	7.3	1.6	0.0
Block Island	26	11	46	30.00	30.03	-.03	36.5	+0.5	56	18	42	16	12	31	22	34	31	80	4.47	+0.7	10	12,566	w.	51	e.	23	10	4	17	6.5	6.6	0.0
Providence	160	215	251	29.87	30.05	-.01	32.0	+0.4	52	14	38	7	12	26	23	29	24	73	3.84	+0.5	14	6,808	n.	38	n.	31	11	7	13	5.9	8.5	T.
Hartford	159	122		29.89	30.07	.00	30.7	+0.9	50	14	36	4	12	25	19				3.85	-0.1	15		sw.				5	9	17	6.8	7.4	0.0
New Haven	106	74	153	29.95	30.07	.00	32.2	-0.3	53	15	38	6	12	26	20	29	24	75	4.35	+0.3	13	5,975	n.	28	ne.	23	9	7	15	6.5	7.2	0.0
Middle Atlantic States							37.0	+1.4										75	2.56	-0.7										6.5		
Albany	97	107	115	29.95	30.06	-.02	28.2	-0.3	47	18	34	-1	12	22	23	26	22	78	2.16	-0.4	11	4,731	sw.	20	ne.	11	5	9	17	7.4	9.4	2.0
Binghamton	871	10	84	29.06	30.02	-.07	29.9	+1.7	57	19	37	0	12	23	31				2.94	+0.6	17	3,842	w.	19	sw.	31	1	11	19	8.1	14.6	1.5
New York	314	414	454	29.72	30.07	-.02	36.1	+1.1	55	15	43	14	12	30	29	32	26	72	3.23	-0.4	11	9,971	w.	48	nw.	31	6	8	17	7.2	5.7	0.0
Bellefonte	1,050	5	36	28.91	30.05		30.2		57	19	38	2	1	23	32	28	25	81	1.96		12		w.				1	6	24	8.6	5.9	0.1
Harrisburg	374	94	104	29.68	30.10	-.02	33.4	+0.7	63	15	40	13	4	27	28	30	24	71	2.40	-0.6	10	3,756	sw.	22	sw.	20	4	9	18	7.1	10.2	T.
Philadelphia	114	123	367	29.96	30.09	-.02	38.2	+1.9	65	19	44	16	1	32	26	34	29	71	2.98	-0.4	8	8,127	sw.	37	ne.	23	6	9	16	6.4	2.8	0.0
Reading	325	81	98	29.72	30.09		34.0		62	15	40	14	1	28	28	31	26	74	2.51	-1.0	11	3,598	w.	19	w.	20	6	8	17	7.2	11.0	T.
Scranton	805	111	119	29.17	30.06	-.04	32.1	+1.4	60	19	39	11	1	26	26	30	26	79	3.25	+0.2	15	4,558	sw.	23	sw.	20	0	8	23	8.4	9.7	1.4
Atlantic City	52	37	172	30.02	30.08	-.02	39.2	+2.8	66	15	46	16	1	32	24	36	32	79	2.67	-1.3	9	11,038	w.	60	ne.	23	11	5	15	5.7	0.1	0.0
Cape May	17	13	49				39.5	+1.5	64	14	46	18	1	33	24	36	33	80	1.72		10		nw.				9	13	9		0.5	0.0
Sandy Hook	22	10	55	30.04	30.06		35.0		54	15	40	17	1	30	22	32	28	78	3.19	-0.8	9	9,589	w.	44	ne.	23	6	9	16	6.7	1.6	0.0
Trenton	190	159	183	29.86	30.07		35.0		60	15	42	14	12	28	29	31	26	75	3.08	-0.3	9	6,374	sw.	30	w.	21	9	6	16	6.6	2.9	T.
Baltimore	123	100	215	29.95	30.09	-.04	38.7	+1.5	71	14	46	16	1	32	29	35	30	73	2.46	-0.9	9	5,726	sw.	29	w.	21	10	6	15	6.1	3.6	0.0
Washington	112	62	85	29.96	30.09	-.04	38.4	+1.8	70	15	46	15	1	31	30	34	29	73	2.20	-1.1	8	3,659	s.	28	nw.	29	9	9	13	6.3	1.5	0.0
Cape Henry	18	8	54	30.07	30.10		45.2		75	19	54	17	1	36	36	40	36	75	2.19	-1.2	10	8,019	sw.	34	nw.	2	12	9	10	5.2	0.4	0.0
Lynchburg	681	153	188	29.36	30.13	-.01	40.9	+1.4	71	15	51	10	1	31	36	36	30	68	1.87	-1.4	12	5,409	w.	27	nw.	29	15	7	9	4.8	4.9	0.0
Norfolk	91	170	205	30.02	30.12	-.01	45.4	+2.3	71	19	54	17	1	37	32	39	34	70	1.83	-1.5	8	8,774	sw.	33	nw.	29	13	7	11	4.8	0.1	0.0
Richmond	144	11	52	29.96	30.12	-.02	41.4	+1.6	71	15	50	12	1	32	31	36	32	76	2.70	-0.6	12	5,382	sw.	35	sw.	19	13	10	8	4.5	3.0	0.0
Wytheville	2,304	49	55	27.68	30.14	-.01	36.1	+0.8	61	11	44	3	1	28	43	33	29	79	1.94	-1.0	10	5,915	w.	27	w.	30	11	6	14	5.8	10.0	T.
South Atlantic States							47.6	+0.2										77	3.66	+0.3										4.7		
Asheville	2,253	70	84	27.74	30.18	+.02	38.8	+1.0	67	16	49	8	1	28	43	34	29	77	1.40	-1.8	7	5,252	nw.	26	n.	24	15	5	11	4.5	3.2	0.0
Charlotte	779	55	62	29.29	30.15	-.01	43.6	+0.6	73	15	53	17	1	34	38	38	34	77	3.54	-0.3	7	3,563	s.	21	w.	29	15	5	11	4.8	2.3	0.0
Greensboro	886	5	56	29.16	30.14		40.0		71	14	51	9	1	29	38	34	32	83	3.10		10	5,204	sw.	34	nw.	29	13	7	11	5.0	1.1	0.0
Hatteras	11	5	50	30.10	30.11	-.02	50.1	0.0	70	15	57	26	1	43	28	46	43	82	5.87	+1.7	10	9,092	w.	34	w.	29	14	10	7	4.4	0.0	0.0
Raleigh	376	103	110	29.73	30.14	-.01	44.4	+1.4	74	15	54	16	1	35	34	38	34	73	2.17	-1.4	8	4,436	sw.	30	w.	29	14	6	11	4.9	T.	0.0
Wilmington	78	81	91	30.08	30.17	+.02	49.3	+0.2	76	15	59	20	1	39	31	43	40	80	4.27	+1.5	7	3,989	w.	24	e.	22	16	7	8	4.2	T.	0.0
Charleston	48	11	92	30.12	30.17	+.02	50.7	-1.0	74	16	60	27	20	42	31	46	42	81	3.54	+0.8	6	6,061	w.	38	e.	22	14	6	11	4.8	0.0	0.0
Columbia, S. C	351	41	57	29.78	30.18	+.02	47.0	-0.2	77	16	57	19	1	38	36	41	35	73	3.97	+0.9	9	4,396	sw.	26	sw.	19	14	7	10	4.7	T.	0.0
Due West	711	10	55	29.40	30.19		44.2		76	16	54	18	1	34	37				3.87		8	5,873	sw.	30	sw.	19	15	7	9	4.3	0.5	0.0
Greenville, S. C	1,039	139	146	29.02	30.14		44.4	+2.2	73	14	54	17	20	35	37	39	34	75	3.44	-1.4	9	5,452	sw.	30	sw.	19	17	4	10	4.4	3.3	0.0
Augusta	182	62	77	29.97	30.17	+.01	48.0	-0.1	79	16	58	22	1	38	36	41	37	75	4.61	+1.4	7	3,111	nw.	21	w.	19	15	5	11	4.8	T.	0.0
Savannah	65	150	194	30.11	30.18	+.03	51.6	-0.8	77	15	61	25	20	42	35	45	40	74	4.40	+1.5	8	7,413	w.	30	w.	19	15	3	13	4.9	0.0	0.0
Jacksonville	43	209	245	30.13	30.18	+.04	55.2	-1.1	77	16	64	25	20	46	37	48	44	74	3.02	0.0	6	7,401	nw.	20	w.	19	12	9	10	4.9	0.0	0.0
Florida Peninsula							66.6	+0.1										81	5.41	+3.6										5.3		
Key West	22	10	64	30.08	30.10	+.02	70.0	-0.3	84	8	75	55	26	65	16	66	65	87	3.96	+2.3	13	7,611	ne.	32	nw.	19	12	7	12	5.6	0.0	0.0
Miami	25	141	168	30.10	30.13	+.01	68.6	+0.6	82	8	74	44	26	63	25	63	60	78	9.03	+7.3	14	7,844	e.	28	e.	1	5	12	14	6.7	0.0	0.0
Tampa	35	79	87	30.12	30.16	+.04	61.1	0.0	80	16	71	33	24	51	31	54	51	79	3.25	+1.2	7	4,387	ne.	16	n.	8	11	10	10	5.1	0.0	0.0
Titusville	44	5		30.11	30.16		60.2		83	18	71	31	24	50	32				2.30		10		nw.				17	5	9	3.8	0.0	0.0
East Gulf States							47.9	-1.5										76	2.84	-2.0										4.8		
Atlanta	1,173	190	216	28.91	30.18	+.02	43.7	-1.0	71	15	52	13	20	36	27	39	34	73	1.77	-2.9	6	7,516	nw.	34	nw.	2	15	4	12	4.7	2.1	0.0
Macon	370	78	87	29.79	30.20	+.04	45.9	-1.6	75	16	57	19	1	35	34	40	35	75	3.52	-0.5	6	3,569	nw.	19	nw.	2	14	6	11	4.4	T.	0.0
Thomasville	273	49	58	29.89	30.19	+.04	51.5	-1.0	78	16	62	20	20	40	31	44	40	75	2.82	-1.5	7	2,827	nw.	22	sw.	22	13	7	11	5.0	T.	0.0
Apalachicola	36	42	49	30.15	30.19		51.0		73	11	50	25	20	43	28	47	44	80	1.66	-3.5	5	5,076	nw.	27	e.	22	14	7	10	4.7	T.	0.0
Pensacola	56	149	185	30.14	30.20	+.05	50.6	-3.4	69	7	58	20	20	43	34	47	44	82	2.12	-2.5	6	7,656	n.	36	s.	7	12	6	13	5.1	T.	0.0
Anniston	741	9	57	29.40	30.22	+.06	43.3	-0.9	73	16	55	14	3	32	37				2.90	-2.2	8	3,277	nw.	16	nw.	19	16	7	8	3.9	5.1	0.0
Birmingham	700	11	48	29.42	30.21	+.05	45.8	-0.6	74	12	55	13	3	36	34	40	35	74	2.97	-2.2	10	4,469	s.	23	sw.	18	14	9	8	4.4	5.5	0.0
Mobile	57	125	161	30.14	30.20	+.05	50.1	-2.1	76	12	59	21	20	41	34	45	41	78	4.92	-0.1	8	6,126	n.	33	se.	17	12	10	9	4.9	T.	0.0
Montgomery	223	100	112	29.96	30.22	+.06	47.3	-2.1	75	16	57	20	3	37	31	42	36	71	3.32	-1.5	6	4,064	nw.	22	nw.	18	14	7	10	4.6	T.	0.0
Corinth	469	6					44.7		74	12	54	9	23	35	33				3.58		10		se.				6	16	9		9.2	0.0
Meridian	375	87	95	29.79	30.20	+.04	47.0	-0.7	78	13	58	12	24	36	37	41	37	77	2.39	-2.8	9	3,519	sw.	19	nw.	18	14	7	10	4.6	6.9	0.0
Vicksburg	247	65	73	29.93	30.22	+.07	49.0	-1.0	75	12	58	19	20	40	38	43	38	71	2.80	-2.4	8	4,787	se.	24	nw.	18	11	5	15	5.6	8.9	0.0
New Orleans	53	76	84	30.15	30.21	+.08	53.2	-2.4	79	13	61	26	20	45	33	48	45	80	2.85	-1.9	7	4,006	e.	19	nw.	18	10	6	15	5.9	T.	0.0
West Gulf States							51.1	+0.6										76	2.49	-0.4										4.7		
Shreveport	249	77	93	29.92	30.20	+.07	48.6	-0.5	75	10	57	15	19	40	29	44	40	77	6.25	+2.0	12	3,961	se.	24	nw.	18	12	8	11	5.0	11.0	0.0
Bentonville	1,303	11	44	28.70	30.10	-.03	41.2	+3.7	73	11	51	0	19	32	34				2.71		9	4,643	s.	23	s.	5	21	1	9		1.0	0.0
Fort Smith	457	79	94		30.14	+.01	44.5	+2.4	75	11	55	7	19	34	35			76	4.12	+1.4	9	5,072	e.	26	nw.	18	13	7	11		T.	0.0
Little Rock	357	136	153	29.77	30.16	+.02	46.1	+1.9	76	14	55	13	19	37	31	41	36	73	3.81	-0.3	10	5,926	sw.	26	nw.	18	12	5	14	5.3	0.6	0.0
Austin	605	136	148	29.52	30.16		52.6	+1.6	79	10	64	16	23	42	40	46	42	73	2.48	-0.2	7	5,529	s.	39	n.	18	14	7	10	4.3	5.5	0.0
Brownsville	57	83	100	30.10	30.16		61.0	-0.2	83	14	70	29	22	52	30	54	51	81	0.62	-0.9	6	6,688	se.	32	se.	6	8	19	4	4.8	T.	0.0
Corpus Christi	20	11	78	30.15	30.17	+.05	56.4	-1.6	81	17	64	28	22	49	27	52	50	85	2.14	+0.7	12	6,669	e.	35	nw.	18	11	6	14	5.5	T.	0.0
Dallas	512	220	227	29.61	30.17		49.2		77	10	58	14	19	40	34				1.54	-0.8	6	8,200	se.	40	nw.	18	16	4	11	4.4	0.1	0.0
Fort Worth	670	106	114	29.41	30.14	+.02	50.8	+3.3	79	11	62	15	19	40	39	44	37	68	0.41	-1.5	5	6,123	s.	26	sw.	31	16	6	9	3.8	T.	0.0
Galveston	54	106	114	30.14	30.20	+.08	53.1	-3.3	75	7	59	23	19	47	28	50	48	85	3.28	-0.5	7	7,216	se.	33	nw.	18	16	5	10	4.7	T.	0.0
Groesbeck	461	11	56	29.68	30.17		49.6		77	10	59	8	23	40	32				1.47	-1.7	4	7,510	s.	36	nw.	18	16	7	8	3.9	8.0	0.0
Houston	138	292	314	30.05	30.20		54.2	-0.2	81	9	63	20	19	45	28				1.68	-2.6	7	8,432	e.	37	nw.	18	12	6	13	5.3	2.5	0.0
Palestine	510	64	72	29.64	30.19	+.07	50.0	+0.1	77	11	59	14	19	41	33	45	40	74	3.21	-0.5	7	5,340	s.	26	nw.	18	14	7	10	4.6	9.5	0.0
Port Arthur	34	58	66	30.15	30.19		53.6		76	9	61	23	19	46	40				4.56		6	4,895	se.	30	n.	2	12	4	15	5.4	1.5	0.0
San Antonio	693	119	132	29.43	30.18	+.07	54.6	+0.9	80	8	65	21	22	44	33	47	42	68	2.08	+0.5	8	4,255	sw.	30	nw.	17	13	8	10	4.7	2.9	0.0
Taylor	583	55	63	29.59	30.21	+.10	50.9	+0.3	79	9	62	12	23	40	38				1.83	-0.5	8	5,513	s.	28	nw.	18	15	6	10	4.1	5.6	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1929*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F		° F	° F.		° F	° F.	° F.	° F.	%	In.	In.		Miles								0-10	In.	In.
Ohio Valley and Tennessee							37.2	+0.6										80	3.02	−0.5										6.9		
Chattanooga	762	190	215	29.35	30.19	+.03	41.6	−1.7	71	15	51	9	3	32	31	37	32	73	2.89	−2.2	11	4,672	sw.	27	nw.	29	13	8	10	4.8	9.5	0.0
Knoxville	995	102	111	29.08	30.17	+.01	39.4	−0.9	71	16	48	10	3	30	30	37	34	84	2.73	−1.8	12	4,005	sw.	24	sw.	20	12	8	11	5.3	6.6	0.0
Memphis	399	76	97	29.73	30.16	+.01	45.4	+1.8	70	14	52	12	20	38	37	41	37	77	3.25	−1.3	9	5,766	sw.	29	n.	18	11	6	14	5.7	3.3	0.0
Nashville	546	168	191	29.58	30.18	+.03	42.2	+1.2	69	12	50	6	3	34	39	38	34	76	3.33	−0.9	10	5,875	s.	28	w.	18	10	6	15	6.1	7.3	0.0
Lexington	989	193	230	29.04	30.14	.00	36.3	+0.5	65	12	44	−2	3	29	38				1.88	−1.9	14	10,057	sw.	38	sw.	18	8	6	17	6.6	5.6	0.0
Louisville	525	188	234	29.53	30.13	−.01	37.2	−0.4	66	12	44	2	3	30	31	35	31	80	3.24	−0.5	13	7,655	s.	27	nw.	18	7	6	18	6.8	5.4	0.0
Evansville	431	76	116	29.65	30.14	+.01	37.9	+0.7	66	12	45	4	3	31	28	35	32	82	3.51	0.0	11	6,929	sw.	32	sw.	13	9	3	19	6.8	5.8	0.0
Indianapolis	822	194	230	29.16	30.07	−.05	31.7	−0.5	62	13	38	−2	3	25	27	29	25	80	4.14	+1.2	16	7,814	sw.	34	ne.	18	6	8	17	7.3	8.0	0.0
Royal Center	736	11	55	29.25	30.08		27.0		59	13	34	−5	3	20	28				2.80	+0.1	16	7,483	sw.	43	n.	18	4	6	21	8.0	12.9	3.7
Terre Haute	575	96	129	29.44	30.08		32.6		64	12	40	−2	3	25	26	30	28	86	3.98	+1.0	13	6,658	sw.	38	n.	18	6	8	17	6.9	12.9	0.0
Cincinnati	627	11	51	29.40	30.10	−.03	34.4	+1.0	64	12	41	1	3	28	26	32	30	85	2.43	−0.6	16	6,013	sw.	23	sw.	30	7	5	19	7.2	7.1	0.0
Columbus	822	179	222	29.17	30.07	−.05	33.1	+0.7	59	13	39	8	3	27	24	31	28	84	3.81	+1.1	16	6,455	sw.	30	nw.	8	2	8	21	8.0	10.7	T.
Dayton	899	137	173	29.09	30.08		32.6	0.0	60	12	38	0	3	27	24	31	28	86	3.21	+0.5	17	7,019	sw.	26	sw.	20	4	7	20	7.7	7.4	0.0
Elkins	1,947	59	67	27.99	30.12	.00	36.5	+3.8	67	17	45	−8	1	28	43	33	29	78	2.41	−1.0	18	4,325	w.	22	sw.	31	4	6	21	7.5	9.1	0.0
Parkersburg	637	77	82	29.44	30.11	−.03	37.4	+2.2	65	17	44	8	1	30	25	33	29	74	2.48	−0.6	18	4,133	sw.	18	sw.	6	7	3	21	7.7	13.1	0.0
Pittsburgh	842	353	410	29.14	30.07	−.04	34.6	+0.4	63	17	41	8	1	28	22	32	28	80	2.15	−0.7	14	7,683	sw.	34	nw.	8	1	6	24	8.4	11.4	T.
Lower Lake Region							27.6	−1.5										84	3.57	+0.8										8.9		
Buffalo	767	247	280	29.16	30.02	−.04	27.4	−2.4	48	13	33	7	12	22	33	25	23	86	5.22	+1.9	22	13,297	w.	64	w.	21	1	3	27	9.1	31.1	6.0
Canton	448	10	61	29.54	30.04		17.3	−5.4	40	27	25	−23	12	10	42				2.42	−0.3	23	7,513	w.	31	e.	19	2	5	24	8.5	22.4	10.3
Ithaca	836	5	100	29.10	30.04		27.4		49	27	34	−5	12	20	35	26	23	84	2.87	+0.5	17	5,946	nw.	29	se.	12	1	6	24	8.8	13.3	1.4
Oswego	335	76	91	29.66	30.04	−.02	26.8	−2.2	41	31	33	1	12	21	20	25	23	84	3.07	−0.4	21	7,000	s.	30	w.	21	0	3	28	9.3	21.0	4.8
Rochester	523	86	102	29.45	30.05	−.01	27.4	−1.9	46	13	32	4	12	22	29	25	22	81	3.52	+0.8	20	6,446	w.	29	w.	31	1	1	29	9.4	19.3	1.0
Syracuse	596	65	79	29.37	30.04	−.03	28.0	−0.3	47	13	34	−3	12	22	36				3.33	+0.2	21	4,716	w.	24	sw.	31	2	5	24	8.6	21.0	3.0
Erie	714	130	166	29.24	30.03	−.04	29.9	−2.0	52	13	35	7	1	25	22	27	24	77	4.38	+1.6	20	10,599	s.	42	sw.	30	0	2	29	9.5	10.6	1.0
Cleveland	762	267	337	29.18	30.03	−.06	32.0	+0.8	61	13	38	7	1	26	31	29	25	79	2.68	+0.2	15	10,601	sw.	44	s.	20	2	2	27	8.8	6.9	T.
Sandusky	629	5	67	29.36	30.06	−.03	30.0	−1.2	59	13	35	7	1	25	25				3.82	+1.5	17	7,025	sw.	28	sw.	20	1	7	23	8.5	11.5	0.6
Toledo	628	208	243	29.34	30.05	−.03	29.0	−1.4	53	13	34	5	19	24	21	27	24	83	3.42	+1.1	15	10,150	sw.	46	n.	18	2	5	24	8.5	15.2	2.5
Fort Wayne	856	113	124	29.09	30.05		28.6	+1.3	59	13	34	5	22	23	26	26	25	88	3.27	+0.7	15	6,932	sw.	29	sw.	20	3	2	26	8.8	14.9	4.5
Detroit	730	218	258	29.21	30.03	−.04	27.1	−2.2	45	13	32	5	20	22	18	26	25	90	4.79	+2.4	15	8,293	w.	46	sw.	20	0	3	28	9.2	27.4	7.0
Upper Lake Region							23.3	−1.4										87	1.94	−0.2										8.7		
Alpena	609	13	92	29.33	30.02	.00	23.4	−1.4	40	30	28	5	22	19	17	22	20	86	1.55	−0.5	21	7,508	w.	33	nw.	30	1	2	28	9.2	21.7	9.8
Escanaba	612	54	60	29.34	30.04	+.01	20.6	−1.8	44	30	27	0	1	15	29	20	18	87	1.78	0.0	13	7,059	nw.	37	n.	19	1	7	23	8.6	21.8	11.0
Grand Haven	632	54	89	29.30	30.02	−.03	27.2	−2.1	45	30	32	3	22	22	19	27	26	92	1.76	−0.7	15	8,487	w.	36	w.	20	1	0	30	9.6	15.9	0.5
Grand Rapids	707	70	87	29.23	30.03	−.02	26.9	−1.6	45	30	32	4	22	22	17	26	23	84	2.71	+0.1	14	4,217	se.	17	nw.	30	0	3	28	9.5	28.9	1.0
Houghton	668	64	99	29.28	30.04	+.02	19.6	−2.2	38	30	25	−7	23	14	29				2.83	−0.2	24	6,409	e.	31	w.	21	2	3	26	9.0	26.5	13.0
Lansing	878	6	49	29.04	30.01		24.8	−2.4	42	30	30	0	20	20	19	25	24	96	3.22	+1.2	20	3,633	sw.	21	ne.	18	2	2	27	9.1	29.3	5.5
Ludington	637	60	66	29.29	30.00		27.4	−1.0	43	30	32	8	19	23	17	25	23	84	0.82	−1.7	12	7,618	e.	30	sw.	25	1	4	26	9.0	9.3	0.0
Marquette	734	77	111	29.20	30.03	+.01	21.8	−0.8	42	30	27	5	1	17	22	20	18	86	3.47	+0.8	23	6,648	w.	30	w.	30	0	2	29	9.4	33.8	17.7
Port Huron	638	70	120	29.30	30.02	−.04	26.0	−1.6	43	30	31	6	20	21	18	25	23	87	2.93	+0.9	16	7,618	sw.	36	ne.	18	0	5	26	8.9	33.3	10.0
Sault Sainte Marie	614	11	52	29.32	30.05	+.05	16.8	−3.7	36	14	23	−8	11	10	23	16	14	90	1.34	−1.0	21	5,630	e.	33	nw.	21	2	7	22	8.4	13.7	15.3
Chicago	673	7	131	29.29	30.04	−.04	28.6	−0.2	47	13	34	1	3	24	23	27	24	84	1.84	−0.2	14	7,545	w.	39	ne.	18	4	3	24	8.2	20.2	2.5
Green Bay	617	109	141	29.33	30.02	−.02	22.1	−0.2	46	30	28	0	21	16	22	21	19	84	0.91	−0.8	9	7,586	n.	32	n.	18	1	5	25	8.6	9.9	0.5
Milwaukee	681	125	221	29.26	30.02	−.04	27.4	+1.3	51	30	33	3	3	22	21	26	22	82	1.08	−0.6	9	9,968	w.	38	n.	18	3	4	24	8.5	11.2	T.
Duluth	1,133	5	47	28.78	30.07	+.02	13.6	−2.3	41	30	20	−17	18	7	24	12	9	84	0.92	−0.2	13	8,921	nw.	46	nw.	26	9	8	14	6.1	12.6	6.0
North Dakota							11.2	−1.2										86	0.80	+0.2										6.0		
Moorhead	940	50	58	29.05	30.12	+.04	12.2	+0.7	42	30	20	−22	18	4	33	11	10	90	0.82	+0.1	10	6,083	n.	25	nw.	30	4	7	20	7.5	11.3	0.8
Bismarck	1,674	8	57	28.26	30.14	+.06	13.6	−1.1	47	4	22	−27	18	5	35	12	9	83	0.81	+0.2	6	6,333	nw.	36	nw.	24	11	7	13	5.4	13.8	3.7
Devils Lake	1,478	11	44	28.45	30.12	+.06	7.6	−1.9	39	25	15	−31	18	0	29	6	4	88	0.87	+0.3	13	7,039	w.	31	nw.	30	9	8	14	5.9	12.6	10.0
Ellendale	1,457	10	56	28.47	30.11		14.4		45	29	23	−19	18	6	33				0.23	−0.2	7	9,827	nw.	38	nw.	30	7	9	15	6.5	4.9	T.
Grand Forks	833	12	67				9.4		40	30	18	−27	18	1	30	9			0.65		10		nw.		nw.	24	8	14	9		6.7	3.0
Williston	1,878	41	48	28.06	30.15	+.09	11.2	−2.6	45	29	20	−36	18	2	35	9	7	85	1.29	+0.7	8	5,404	w.	35	nw.	26	12	10	9	4.8	12.9	6.1
Upper Mississippi Valley							27.4	+0.6										85	0.97	−0.7										6.8		
Minneapolis	918	102	208	29.04	30.06		18.0	−1.6	46	30	25	−13	19	11	29				0.36	−0.6	7	7,606	nw.	34	nw.	30	6	10	15	6.5	5.3	T.
St. Paul	837	236	261	29.12	30.07	−.01	18.2	−0.8	47	30	25	−12	19	11	30				0.36	−0.7	7	7,594	w.	38	sw.	30	7	11	13	6.7	6.3	0.2
La Crosse	714	11	48	29.25	30.05	−.03	22.6	+0.3	53	30	30	−4	22	16	30	20	19	88	0.42	−0.9	7	3,400	w.	15	n.	18	8	6	17	6.6	7.3	0.0
Madison	974	70	78	28.95	30.05	−.03	23.9	+1.1	50	30	30	−1	3	18	23	22	20	85	0.40	−1.2	13	6,040	w.	34	n.	18	4	7	20	7.6	3.0	T.
Wausau	1,247	4	64	28.66	30.05		19.6		43	30	25	−2	21	14	27				0.45	−1.0	8	4,555	w.	23	w.	30	4	5	22	8.0	6.2	1.1
Charles City	1,015	10	51	28.96	30.09	−.01	21.4	+1.0	52	30	29	−8	19	14	33	20	18	91	0.25	−1.0	4	4,407	nw.	18	n.	18	8	11	12	5.9	4.9	0.0
Davenport	606	71	79	29.38	30.07	−.03	28.4	+1.3	61	30	35	−1	3	22	28	26	23	85	0.53	−1.0	8	6,916	w.	31	n.	18	6	8	17	7.0	5.3	0.0
Des Moines	861	84	97	29.15	30.10	−.01	26.9	+0.9	61	30	35	−6	19	19	35	24	22	84	0.34	−0.9	10	6,594	nw.	30	n.	18	9	8	14	6.1	4.5	0.0
Dubuque	700	81	96	29.28	30.06	−.04	25.6	+0.9	56	30	32	−4	3	19	30	24	22	86	0.54	−0.9	12	4,310	nw.	23	n.	18	4	7	20	7.5	6.3	0.0
Keokuk	614	64	78	29.40	30.10	−.02	30.0	+0.4	59	30	38	−1	3	23	31	28	24	81	0.69	−0.8	4	5,263	sw.	25	nw.	28	6	6	19	7.2	7.7	0.0
Cairo	358	87	93	29.74	30.14	−.01	40.3	+2.5	68	15	48	5	20	33	30	37	34	80	4.12	+0.7	12	6,407	s.	29	n.	18	9	4	18	6.7	6.6	0.0
Peoria	609	11	45	29.40	30.09	−.02	28.2	+0.1	55	30	35	−4	3	21	27	26	25	90	1.07	−0.7	9	4,706	w.	24	n.	18	7	9	15	6.5	9.5	T.
Springfield, Ill	636	154	191	29.38	30.08	−.04	30.4	−1.3	64	12	38	−2	3	23	27	28	26	87	1.31	−0.9	9	8,471	sw.	34	n.	18	7	6	18	6.7	10.5	T.
Hannibal	534	74	109	29.50	30.10	−.02	32.0	+0.5	60	30	40	1	3	24	30				0.66	−0.9	10	5,981	sw.	29	n.	18	8	5	18	6.8	2.7	0.0
St. Louis	568	265	303	29.47	30.09	−.04	37.5	+2.8	69	11	45	6	20	30	23	34	29	75	3.07	+0.9	11	8,374	sw.	41	sw.	13	10	6	15	6.0	6.7	0.0
Missouri Valley							29.4	+1.7										78	0.41	−0.7										5.4		
Columbia, Mo	784	6	84	29.24	30.10	−.02	34.4	+1.2	68	11	43	0	19	26	35				0.88	−1.0	10	5,077	sw.	24	n.	18	7	10	14	6.5	3.5	0.0
Kansas City	963	161	181	29.05	30.12	.00	34.8	+2.3	63	30	43	−2	19	27	31	31	27	75	0.65	−0.7	5	6,869	sw.	32	n.	18	11	6	14	5.5	2.7	0.0
St. Joseph	967	11	49	29.04	30.11		31.6		59	30	40	−4	19	23	37	28	25	81	0.18	−0.8	7	5,197	nw.	28	nw.	18	13	7	11	5.3	1.3	0.0
Springfield, Mo	1,324	98	104	28.68	30.12	−.01	39.6	+3.4	72	11	48	−2	19	31	35	35	31	77	1.61	−0.7	9	6,762	s.	26	nw.	18	16	6	9	4.3	4.6	0.0
Iola	984	11	50	29.04	30.13	+.01	35.6	+1.7	71	13	47	0	19	25	37				0.54	−0.8	6	3,555	n.	21	n.	17	11	8	12	5.5	1.4	0.0
Topeka	987	92	107				33.9	+1.9	68	30	43	−1	19	24	37				0.37	−0.6	2	5,594	nw.	31	n.	18	13	9	9	4.8	0.8	0.0
Lincoln	1,189	11	81	28.81	30.13	+.01	28.9	+1.3	62	29	38	−3	19	20	37	25	21	76	0.02	−0.8	1	6,067	s.	34	nw.	24	11	4	16	5.7	0.2	0.0
Omaha	1,105	115	122	28.90	30.13	+.02	27.8	+1.4	62	30	35	−5	19	20	30	25	21	78	0.14	−0.8	5	5,565	nw.	30	nw.	17	15	5	11	5.0	2.0	0.0
Valentine	2,598	47	54	27.32	30.15	+.05	26.6	+2.0	65	14	38	−12	18	15	44	21	18	79	0.41	−0.2	6	5,051	w.	28	nw.	26	14	7	10	4.5	6.5	0.0
Sioux City	1,135	94	164	28.86	30.13	+.01	24.8	+1.7	55	30	33	−8	19	17	37	22	19	80	0.27	−0.6	4	7,952	nw.	44	nw.	26	8	10	13	5.9	3.2	0.0
Huron	1,306	59	74	28.68	30.14	+.04	20.2	+1.5	54	4	29	−16	18	12	39	18	15	80	0.08	−0.5	4	6,243	nw.	27	w.	24	10	7	14	5.9	1.3	0.0
Pierre	1,572	70	75	28.41	30.15	+.05	22.4	+0.6	56	29	31	−13	18	14	32	20	16	76	0.08	−0.4	3	5,731	nw.	31	nw.	26	13	7	11	5.0	0.9	0.0
Yankton	1,233	49	57	28.74	30.11	.00	24.2	+1.4	54	29	33	−12	18	16	35				0.14	−0.7	3	5,390	nw.	27	nw.	26	10	8	13	5.9	1.4	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1929*—Continued

District and station	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind									
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	*° F.*	*° F.*	*° F*		*° F*	*° F.*		*° F*	*° F.*	*° F.*	*° F.*	*%*	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Northern Slope							26.2	+2.3										73	1.05	+0.3										5.5		
Billings	3,140	5	----	----	----	----	22.8	----	51	30	33	−22	19	13	45	----	----	----	0.64	----	6	----	nw.	----	----	----	10	10	11	----	11.6	----
Havre	2,505	11	44	27.39	30.15	+0.10	16.4	−4.0	51	29	24	−30	19	8	38	14	11	82	1.39	+0.8	11	6,264	sw.	33	sw.	24	10	7	14	6.1	21.9	T.
Helena	4,110	87	112	25.79	30.12	−.01	26.2	+2.0	58	14	35	−1	18	17	42	22	16	68	2.58	+1.8	12	4,053	sw.	42	sw.	25	5	5	21	7.3	31.3	5.3
Kalispell	2,973	48	56	26.92	30.06	−.01	28.4	+3.5	51	29	34	11	10	23	27	26	23	82	2.85	+1.4	13	3,753	nw.	22	sw.	25	3	6	22	7.8	21.6	7.5
Miles City	2,371	48	55	27.53	30.20	+.10	17.7	−3.3	51	29	27	−27	19	8	40	15	12	81	0.53	−0.1	7	3,854	s.	28	n.	6	12	10	9	5.0	6.1	0.6
Rapid City	3,259	50	58	26.63	30.20	+.11	27.0	+0.1	63	14	38	−15	18	16	45	21	16	72	0.24	−0.2	6	4,194	w.	29	nw.	26	13	8	10	5.2	3.3	0.0
Cheyenne	6,088	84	101	23.99	30.11	+.02	33.3	+4.8	60	15	43	−2	19	23	32	25	15	50	0.11	−0.4	2	9,618	w.	52	w.	27	11	13	7	4.8	1.6	T.
Lander	5,372	60	68	24.64	30.15	.00	29.1	+8.7	58	13	41	−11	2	18	33	23	19	73	0.23	−0.4	5	3,780	sw.	60	sw.	9	18	10	3	4.1	4.8	T.
Sheridan	3,790	10	47	26.10	30.17	----	20.9	----	60	25	34	−21	19	8	43	17	14	81	0.75	+0.1	5	2,525	nw.	22	nw.	27	9	16	6	4.9	9.4	2.8
Yellowstone Park	6,241	11	48	23.88	30.17	+.01	26.0	+4.4	47	14	33	−4	21	19	25	23	18	73	1.84	+0.3	16	7,097	sw.	36	sw.	12	6	5	20	7.1	8.0	2.5
North Platte	2,821	11	51	27.11	30.15	+.05	31.3	+4.6	66	14	45	−5	18	18	41	23	17	69	0.01	−0.5	1	4,576	w.	29	n.	1	21	3	7	3.0	0.2	0.0
Middle Slope							36.7	+3.2										66	0.42	−0.5										4.2		
Denver	5,292	106	113	24.74	30.11	+.03	37.1	+4.8	66	10	48	−4	2	26	31	28	18	50	0.32	−0.4	3	4,805	s.	30	w.	27	16	14	1	3.4	10.2	0.0
Pueblo	4,685	80	86	25.30	30.10	+.02	35.0	+3.5	73	15	50	−8	2	20	46	26	17	56	0.65	+0.2	4	3,573	nw.	26	nw.	27	16	12	3	3.5	7.7	0.0
Concordia	1,392	50	58	28.64	30.16	+.05	32.3	+1.6	63	30	42	1	19	23	33	27	22	75	0.09	−0.6	8	4,747	nw.	26	nw.	1	13	5	13	5.1	0.2	0.0
Dodge City	2,509	11	51	27.49	30.17	+.07	36.0	+3.4	71	30	50	0	19	22	44	28	22	70	0.05	−0.5	3	5,086	nw.	25	nw.	18	18	6	7	3.3	0.2	0.0
Wichita	1,358	139	158	28.64	30.12	+.01	36.3	+1.7	67	30	46	4	19	26	37	32	26	73	0.04	−1.0	1	6,335	s.	32	n.	18	17	2	12	4.5	0.4	0.0
Broken Arrow	765	11	56	29.29	30.13	----	42.0	----	74	11	53	5	19	31	35	----	----	----	1.23	−0.3	6	8,062	s.	37	n.	18	12	7	12	5.4	0.5	0.0
Oklahoma City	1,214	10	47	28.82	30.13	+.02	43.4	+4.1	74	31	54	8	19	32	39	37	31	70	0.57	−0.9	5	6,336	s.	31	n.	18	15	8	8	4.2	T.	0.0
Southern Slope							45.7	+1.6										58	0.56	−0.3										3.2		
Abilene	1,738	10	52	28.30	30.15	+.04	49.1	+3.1	80	11	61	11	19	38	41	40	31	58	0.14	−1.2	2	6,674	s.	28	s.	11	17	7	7	3.7	0.1	0.0
Amarillo	3,676	10	49	26.32	30.12	+.03	41.3	+4.3	79	10	56	6	19	27	44	31	21	52	0.11	−0.7	2	5,394	sw.	23	ne.	1	22	4	5	2.6	1.6	0.0
Del Rio	944	64	71	29.15	30.16	+.06	51.6	−0.6	77	8	62	22	22	41	38	45	40	71	2.01	+1.3	4	4,466	se.	28	n.	18	15	9	7	3.8	2.2	0.0
Roswell	3,566	75	85	26.45	30.14	+.07	40.9	−0.3	73	13	58	9	22	24	50	32	21	50	0.00	−0.7	0	3,837	s.	30	nw.	6	21	4	6	2.9	0.0	0.0
Southern Plateau							46.0	+4.2										46	0.12	−0.6										1.8		
El Paso	3,778	152	175	26.29	30.16	+.13	44.9	0.0	70	10	58	15	22	32	34	35	24	49	0.50	0.0	2	5,109	nw.	28	w.	7	25	3	3	1.6	5.2	0.0
Santa Fe	7,013	38	53	23.28	30.19	+.13	33.2	+2.5	58	15	45	1	21	22	30	24	15	54	0.11	−0.6	2	3,738	n.	19	n.	6	23	4	4	2.4	1.6	0.0
Flagstaff	6,907	10	59	23.41	30.12	+.06	35.6	+7.2	63	15	54	7	27	17	50	25	----	55	0.01	----	1	5,101	e.	25	n.	20	21	10	0	----	0.0	0.0
Phoenix	1,108	10	107	28,88	30.06	+.02	56.4	+4.4	79	2	73	30	22	40	42	41	25	33	T.	−1.0	0	2,628	e.	16	e.	3	23	7	1	2.0	0.0	0.0
Yuma	141	9	54	29.90	30.05	.00	59.2	+4.0	79	14	74	36	23	45	34	46	30	40	T.	−0.5	0	2,637	n.	20	n.	20	26	4	1	1.4	0.0	0.0
Independence	3,957	6	27	26.07	30.15	+.03	46.6	+7.3	72	1	62	19	22	31	39	34	----	----	T.	−0.8	0	----	nw.	----	----	----	21	7	3	----	0.0	0.0
Middle Plateau							37.3	+7.0										57	0.60	−0.4										4.0		
Reno	4,532	74	81	25.56	30.15	.00	42.5	+8.8	63	1	54	21	28	31	39	36	29	61	1.74	+0.8	7	3,785	w.	31	sw.	9	16	8	7	4.0	0.0	0.0
Tonopah	6,090	12	20	----	----	----	39.7	----	54	1	46	23	20	33	18	32	19	41	T.	----	0	----	se.	----	----	----	----	----	----	----	----	----
Winnemucca	4,344	18	56	25.72	30.18	.00	39.0	+9.0	65	14	53	12	7	26	42	33	26	65	0.72	−0.4	7	4,961	sw.	32	sw.	10	17	8	6	3.9	T.	0.0
Modena	5,473	10	43	24.70	30.16	+.04	35.3	+7.2	60	15	52	5	27	19	42	26	16	52	0.01	−0.8	1	5,986	w.	30	sw.	10	16	9	6	3.6	0.2	0.0
Salt Lake City	4,360	163	203	25.73	30.18	+.03	38.4	+6.5	62	14	46	17	21	31	24	32	24	57	0.43	−1.0	4	4,170	s.	32	s.	10	10	13	8	5.0	5.4	0.5
Grand Junction	4,602	60	68	25.52	30.20	+.10	31.1	+3.6	60	11	44	8	24	18	36	24	18	66	0.10	−0.5	1	2,461	nw.	13	se.	2	16	13	2	3.5	1.4	0.0
Northern Plateau							37.1	+5.6										74	1.84	+0.1										7.4		
Baker	3,471	48	53	26.51	30.16	.00	34.8	+7.5	59	13	43	15	27	27	31	31	27	74	1.59	−0.1	11	4,382	se.	26	sw.	9	8	3	20	6.9	15.5	4.5
Boise	2,739	78	86	27.28	30.21	+.01	37.6	+5.5	65	13	45	14	30	30	26	33	28	70	1.17	−0.4	8	3,276	se.	20	se.	12	6	9	16	6.6	4.8	0.0
Lewiston	757	40	48	29.27	30.10	−.03	39.7	+4.0	60	29	45	24	6	34	26	----	----	----	2.23	+0.7	14	2,182	e.	26	nw.	10	2	5	24	8.5	T.	0.0
Pocatello	4,477	60	68	25.56	30.18	−.01	35.5	+7.8	61	15	44	7	21	27	30	30	23	64	1.01	−0.2	6	6,871	se.	36	s.	10	6	16	9	5.5	3.1	0.0
Spokane	1,929	101	110	28.00	30.09	+.01	34.8	+4.3	53	29	40	17	4	30	27	33	31	86	1.83	−0.4	10	4,086	s.	27	s.	22	0	9	22	8.4	2.5	0.0
Walla Walla	991	57	65	29.01	30.10	−.02	40.0	+4.5	62	29	46	18	3	34	25	36	32	75	3.20	+1.1	12	2,982	s.	21	w.	25	2	3	26	8.7	5.0	0.0
North Pacific Coast Region							44.7	+2.5										87	6.40	−0.2										8.3		
North Head	211	11	56	29.81	30.04	+.01	45.2	+1.1	59	1	49	35	10	41	23	44	42	90	7.08	−2.4	24	10,379	s.	68	s.	25	4	2	25	8.2	0.0	0.0
Port Angeles	29	8	53	----	30.02	----	40.6	----	54	24	45	28	12	36	16	----	----	----	4.53	−0.2	21	3,322	sw.	34	sw.	25	0	9	22	----	3.2	0.0
Seattle	125	215	250	29.89	30.03	+.02	43.6	+1.9	58	25	48	32	10	40	20	42	40	86	5.26	−0.3	20	6,219	s.	53	s.	25	0	5	26	9.1	2.5	0.0
Tacoma	194	172	201	29.83	30.05	+.04	45.0	+4.4	60	25	51	30	4	39	23	----	----	----	6.39	−0.3	21	5,737	s.	44	s.	25	0	5	26	9.0	T.	0.0
Tatoosh Island	86	9	53	29.87	29.97	+.01	44.2	+0.3	54	14	47	34	10	42	18	43	41	91	10.04	−3.3	24	13,957	e.	57	e.	13	3	5	23	8.3	4.0	0.0
Yakima	1,076	58	67	28.92	30.10	----	34.4	----	56	1	42	17	5	26	30	31	28	82	1.13	−0.2	10	2,095	nw.	25	w.	30	8	7	16	6.5	5.4	0.0
Medford	1,425	29	58	28.59	30.12	----	41.1	----	71	13	49	18	7	33	37	40	38	91	6.45	----	15	----	s.	27	se.	9	5	5	21	7.8	0.0	0.0
Portland, Oreg.	153	68	106	29.92	30.08	+.01	45.3	+4.1	59	13	50	34	29	41	24	43	40	82	8.79	+2.1	20	4,014	se.	28	sw.	31	2	2	27	8.9	T.	0.0
Roseburg	510	75	99	29.55	30.11	.00	45.0	+3.2	68	13	51	26	29	39	24	43	42	89	7.94	+2.6	18	1,960	s.	25	sw.	13	0	9	22	8.5	0.0	0.0
Middle Pacific Coast Region							51.7	+3.4										84	3.85	−0.2										6.4		
Eureka	62	73	89	30.06	30.14	+.02	51.0	+2.8	67	13	57	36	26	46	20	50	48	89	7.13	+0.8	15	4,160	se	32	sw.	12	7	3	21	7.2	0.0	0.0
Red Bluff	330	5	58	29.76	30.12	−.02	51.0	+4.9	76	5	59	30	28	43	34	47	42	77	4.18	−0.2	10	5,066	se.	33	se.	12	11	7	13	5.6	0.0	0.0
Sacramento	69	106	117	30.07	30.14	.00	49.4	+3.2	68	13	56	31	2	43	25	47	45	85	4.06	+1.0	8	4,371	se.	25	nw.	19	8	8	15	6.6	0.0	0.0
San Francisco	155	208	243	29.95	30.13	.00	54.2	+2.9	74	5	59	39	30	50	21	52	49	85	3.09	−0.9	14	4,114	n.	32	s.	9	6	11	14	6.4	0.0	0.0
San Jose	141	12	110	29.98	30.14	----	53.0	+3.1	72	5	62	30	29	44	33	----	----	----	0.78	−1.8	6	3,591	nw.	24	s.	9	7	9	15	6.3	0.0	0.0
South Pacific Coast Region							57.9	+4.9										65	0.17	−1.8										4.4		
Fresno	327	80	98	29.80	30.16	+.03	49.6	+3.4	74	14	58	30	31	41	27	46	42	77	0.50	−1.0	4	2,593	nw.	15	nw.	19	7	9	15	6.4	0.0	0.0
Los Angeles	338	159	191	29.70	30.07	.00	63.7	+7.1	86	28	73	49	16	54	28	51	39	50	0.00	−2.6	0	3,124	ne.	14	nw.	17	23	6	2	2.5	0.0	0.0
San Diego	87	62	70	29.95	30.04	−.03	60.3	+4.3	78	24	69	46	23	52	30	53	47	69	0.00	−1.9	0	2,977	nw.	18	nw.	13	12	12	7	4.4	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.93	30.02	----	76.2	−0.1	86	5	81	67	26	71	14				2.88	−3.3	22	9,271	e.	34	e.	21	3	28	0	4.8	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	[1]29.73	[1]29.81	−.01	79.8	−0.2	90	13	87	71	6	72	18	----	----	[2]82	4.17	−1.2	14	5,247	nw.	22	n.	25	1	19	11	6.7	0.0	0.0
Cristobal	38	7	97	[1]29.81	[1]29.83	−.01	81.2	+1.3	87	13	86	71	4	77	13	75	73	[2]78	7.87	−3.2	20	9,256	n.	28	nw.	25	6	20	5	5.3	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[1]29.49	[1]30.08	----	−8.9	----	37	1	−1	−51	31	−17	38	−11	−15	79	0.33	----	4	----	n.	----	----	----	14	3	14	5.0	6.1	10.9
Juneau	80	11	50	[1]29.80	[1]29.89	----	30.3	----	51	2	34	15	10	26	19	28	22	72	4.58	----	15	6,349	e.	52	e.	10	11	3	17	6.0	10.9	0.8
Hawaiian Islands																																
Honolulu	38	86	100	[1]29.90	[1]29.94	----	72.0	----	81	8	76	61	17	68	14	65	62	73	5.99	+2.0	15	6,137	ne.	28	ne.	30	12	7	12	5.8	0.0	0.0

[1] Pressure not reduced to mean of 24 hours.

[2] Observations taken bihourly.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, December, 1929*

Stations	Altitude above mean sea level Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F	99				26.2		33.6	18.8	43	8	5.51		20.2
Sydney, C. B. I	48	29.90	29.95	+0.06	24.9	−3.3	30.7	19.2	40	10	5.07	+0.44	22.5
Halifax, N. S	88	29.88	29.99	+.03	26.4	−1.2	33.2	19.6	50	5	6.09	+0.97	11.4
Yarmouth, N. S	65	29.87	29.94	−.04	30.3	−0.4	36.9	23.8	52	7	5.21	+0.44	19.8
Charlottetown, P. E. I	38	29.87	29.91	−.03	21.6	−2.7	27.4	15.7	42	4	5.35	+1.69	41.0
Chatham, N. B	28	29.88	29.92	−.02	13.8	−3.2	23.1	4.5	36	−17	3.46	+0.24	28.2
Father Point, Que	20												
Quebec, Que	296												
Doucet, Que	1,236				1.6		13.4	−10.2	28	−40	3.30		33.0
Montreal, Que	187	29.82	30.04	+.01	17.7	−0.6	23.4	12.1	39	−5	4.36	+0.71	41.4
Ottawa, Ont	236	29.78	30.07	+.05	16.8	−0.2	23.6	10.0	39	−13	4.06	+1.15	40.0
Kingston, Ont	285												
Toronto, Ont	379	29.60	30.03	−.02	25.3	−1.7	30.9	19.7	41	6	2.29	−0.62	22.2
Cochrane, Ont	930				2.4		9.6	−4.8	29	−27	0.88		8.8
White River, Ont	1,244	28.65	30.04	+.07	3.9	−5.8	13.6	−5.8	32	−35	1.74	+0.03	17.4
London, Ont	808				24.1		29.5	18.7	39	5	5.24		33.3
Southampton, Ont	656	29.26	30.00	−.02	22.2	−4.5	28.2	16.3	38	−3	3.22	−0.76	31.8
Parry Sound; Ont	688	29.30	30.03	+.02	18.1	−3.1	24.2	12.0	36	−8	3.66	−0.82	36.6
Port Arthur, Ont	644	29.34	30.08	+.09	13.0	−0.2	19.6	6.4	39	−7	1.76	+0.89	17.6
Winnipeg, Man	760												
Minnedosa, Man	1,690	28.18	30.11	+.09	4.3	−1.4	12.5	−3.9	39	−31	0.91	+0.29	9.1
Le Pas, Man	860				−1.6		7.0	−10.3	36	−30	0.70		7.0
Qu'Appelle, Sask	2,115	27.73	30.10	+.10	6.4	−1.0	14.5	−1.7	42	−28	1.21	+0.69	12.1
Moose Jaw, Sask	1,759				8.8		18.4	−0.8	43	−40	1.38		12.4
Swift Current, Sask	2,392	27.41	30.07	+.08	13.8	−2.2	20.8	6.9	44	−30	1.43	+0.65	14.2
Medicine Hat, Alb	2,144												
Calgary, Alb	3,428	26.31	30.04	+.10	16.2	−2.0	26.7	5.7	54	−25	1.00	+0.41	10.0
Banff, Alb	4,521	25.28	30.08	+.14	13.8	−5.3	20.3	7.2	40	−20	3.74	+2.53	37.1
Prince Albert, Sask	1,450	28.47	30.15	+.14	0.3	−2.5	10.2	−9.5	39	−41	1.13	+0.39	11.3
Battleford, Sask	1,592	28.27	30.13	+.14	2.3	−3.1	11.8	−7.2	42	−40	0.96	+0.64	9.6
Edmonton, Alb	2,150												
Kamloops, B. C	1,262												
Victoria, B. C	230	29.74	30.00	+.03	42.0	+0.8	45.2	38.8	52	30	4.92	−3.06	2.4
Barkerville, B. C	4,180												
Estevan Point, B. C	20												
Prince Rupert, B. C	170												
Hamilton, Ber	151												

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Stations	Altitude	Station pressure	Sea level pressure	Departure from normal	Mean max. + mean min. ÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
Charlottetown, P. E. I	38	29.85	29.89	−0.07	36.0	+0.5	41.8	30.2	56	7	3.11	−0.86	6.5
Winnipeg, Man	760	29.17	30.04	.00	18.7	+0.7	24.5	12.9	44	−19	0.69	−0.39	6.9
Medicine Hat, Alb	2,144	27.74	30.04	+.04	33.1	+5.7	43.6	22.6	64	−11	0.37	−0.55	3.1
Calgary, Alb	3,428	26.48	30.16	+.18	30.0	+4.2	39.4	20.7	60	−2	1.55	+0.67	15.5
Banff, Alb	4,521	25.48	30.22	+.26	26.7	+0.9	34.7	18.8	49	−13	1.62	−0.65	15.6
Edmonston, Alb	2,150	27.70	30.04	+.07	30.6	+7.7	39.8	21.5	64	−5	1.06	+0.48	6.1
Kamloops, B. C	1,262	29.01	30.35	+.39	34.5	+1.1	39.5	29.6	52	15	0.99	−0.47	1.3
Estevan Point, B. C	20				44.5		50.3	38.8	56	31	5.20		0.0
Prince Rupert, B. C	170				43.7		47.4	40.0	52	32	15.73		0.0
Hamilton, Ber	151	29.97	30.13	+.08	71.2	+2.5	76.5	65.9	81	57	6.21	+1.83	0.0

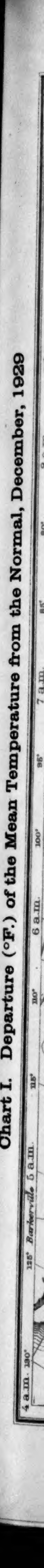


Chart I. Departure (°F.) of the Mean Temperature from the Normal, December, 1929

Chart I. Departure (°F.) of the Mean Temperature from the Normal, December, 1929

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.

Chart II. Tracks of Centers of Anticyclones, December, 1929. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Wilfred P. Day)

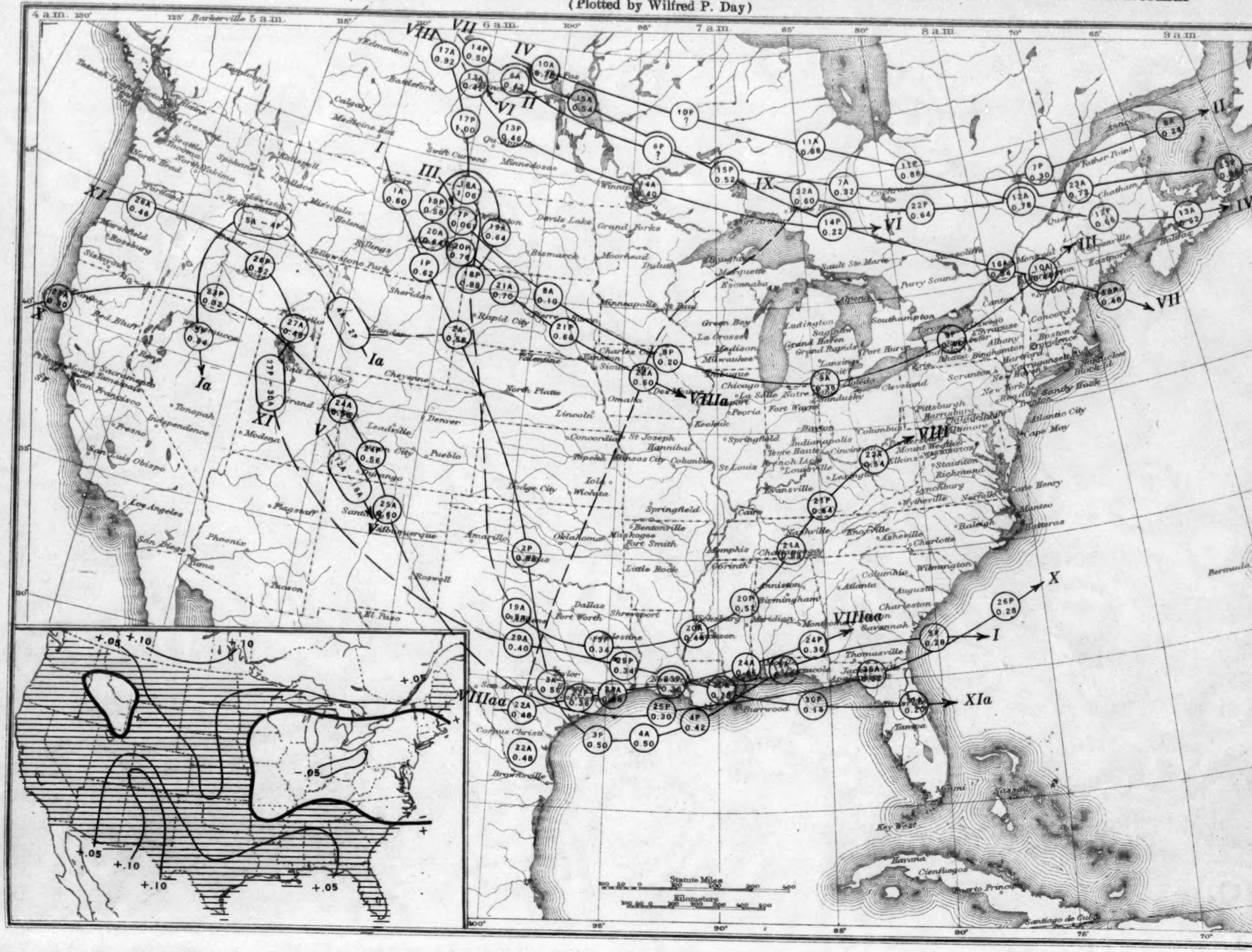


Chart III. Tracks of Centers of Cyclones, December, 1929. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

Chart III. Tracks of Centers of Cyclones, December, 1929. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

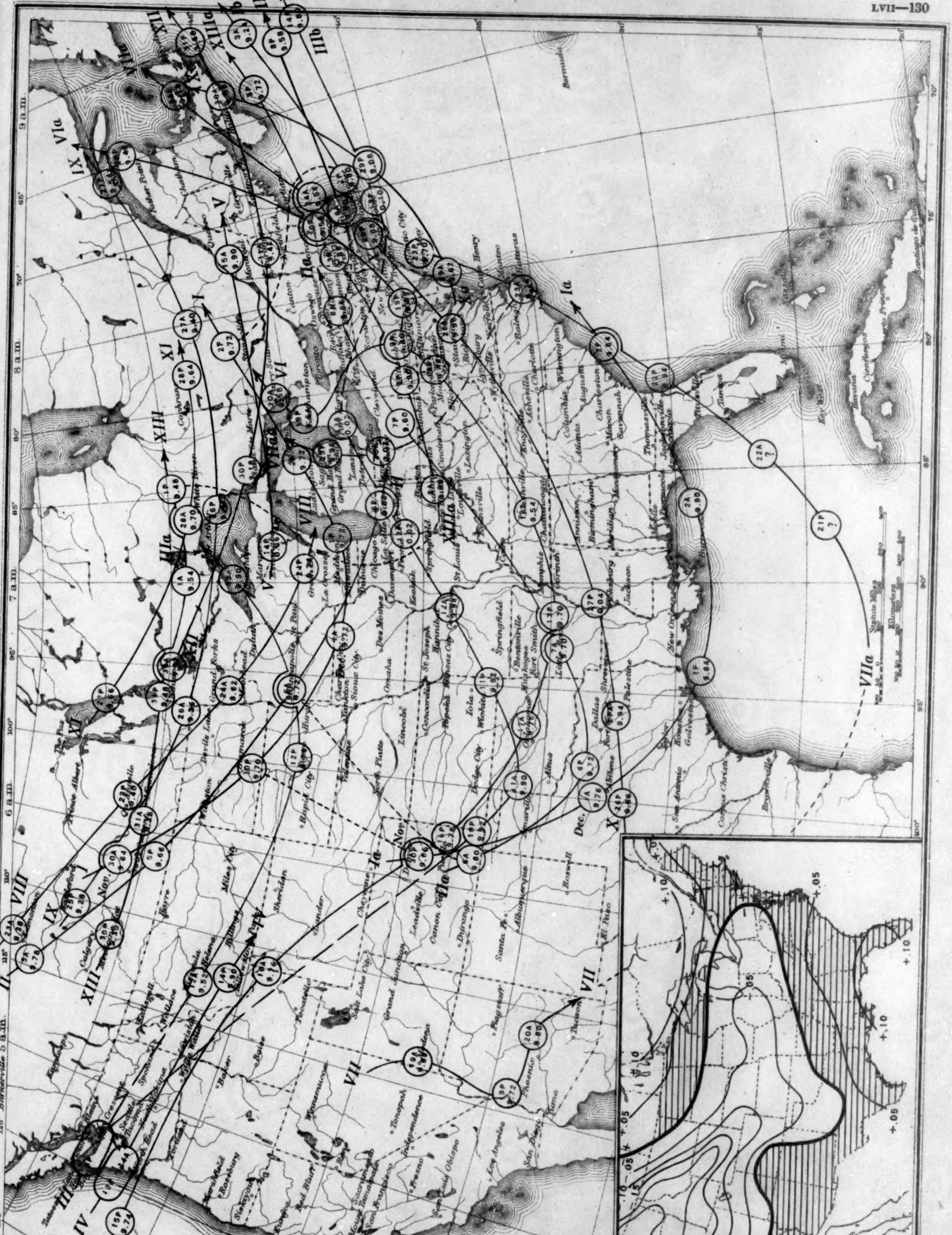


Chart IV. Percentage of Clear Sky between Sunrise and Sunset, December, 1929

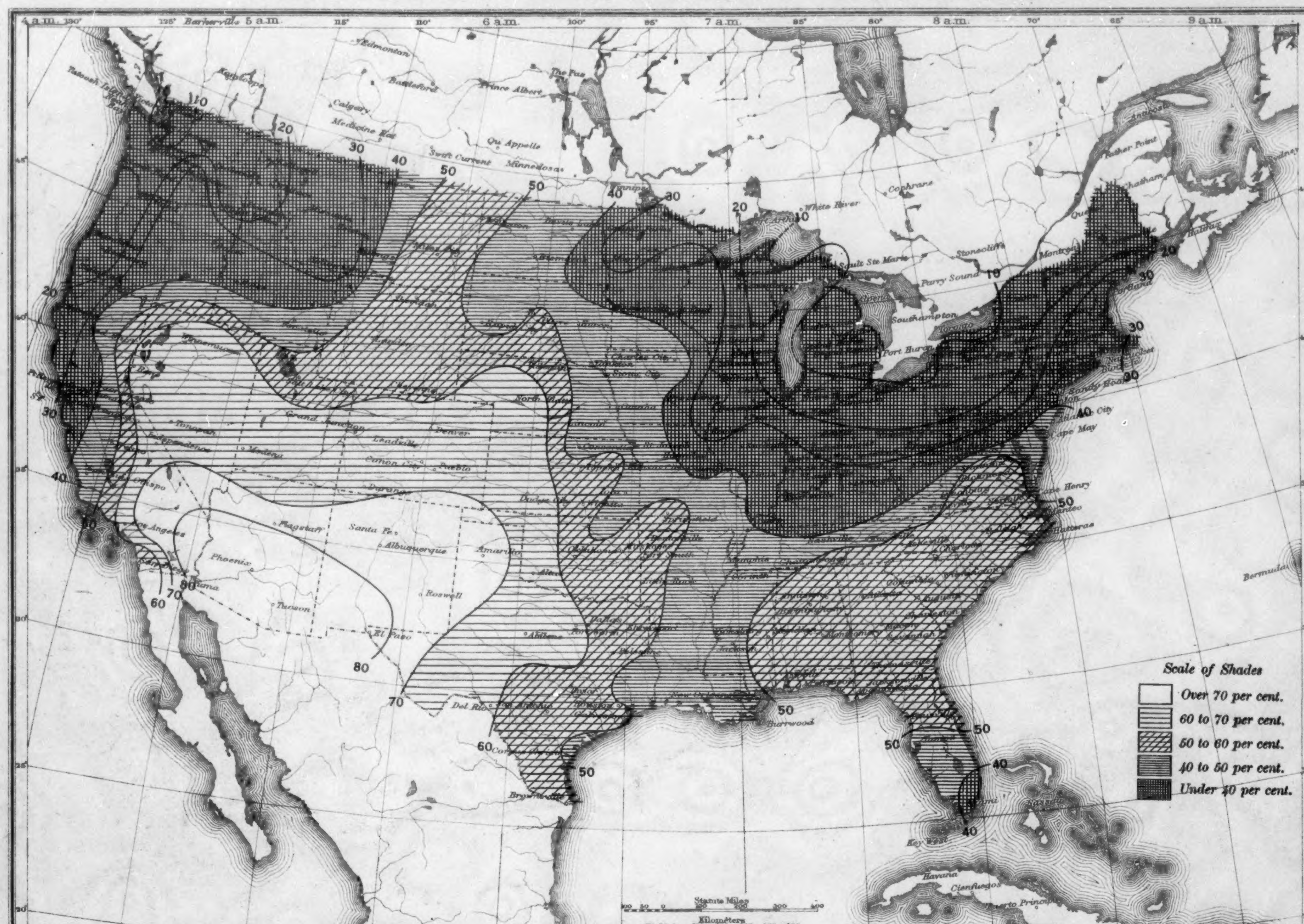


Chart V. Total Precipitation, Inches, December, 1929. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, December, 1929. (Inset) Departure of Precipitation from Normal

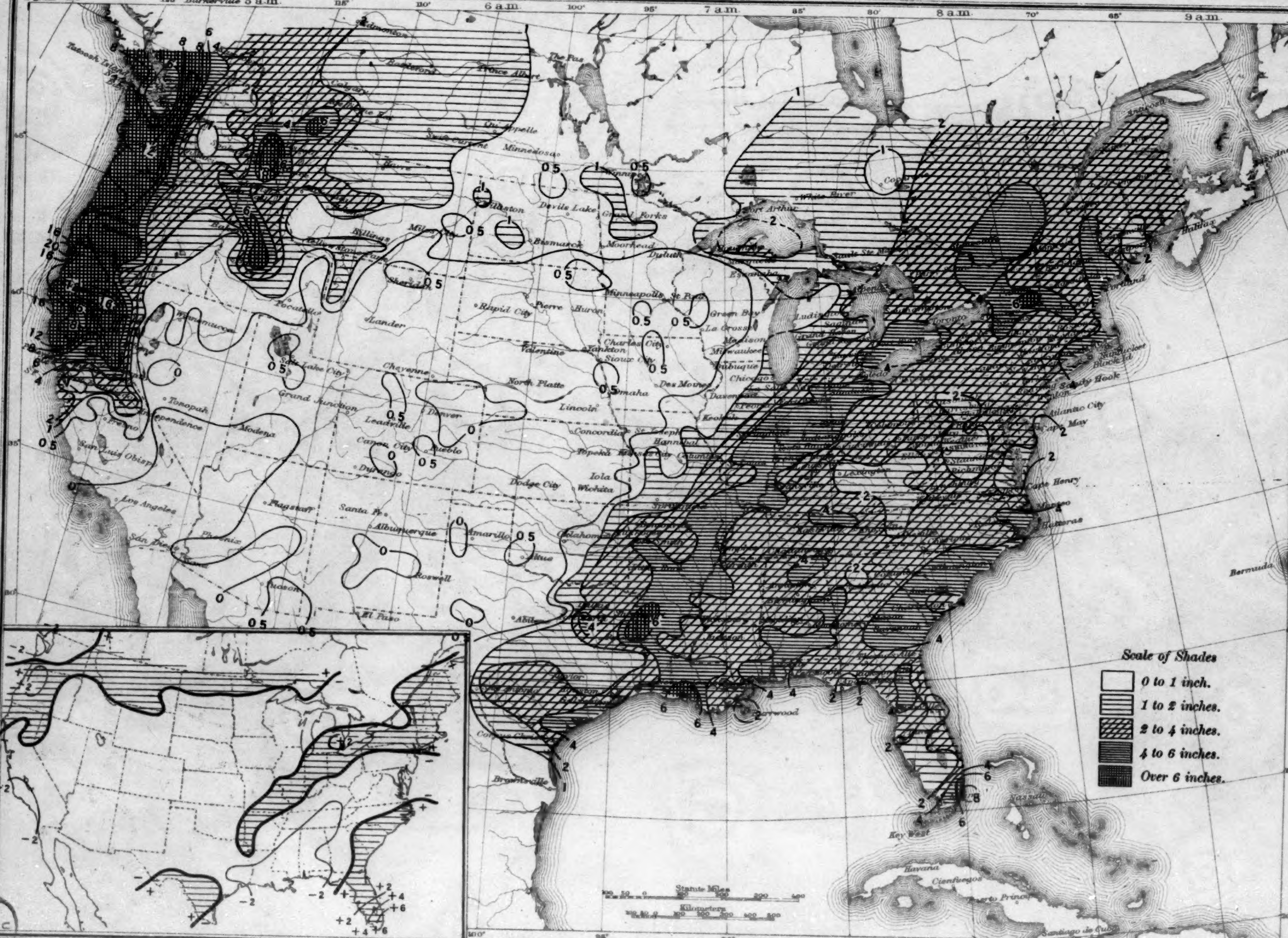


Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, December, 1929

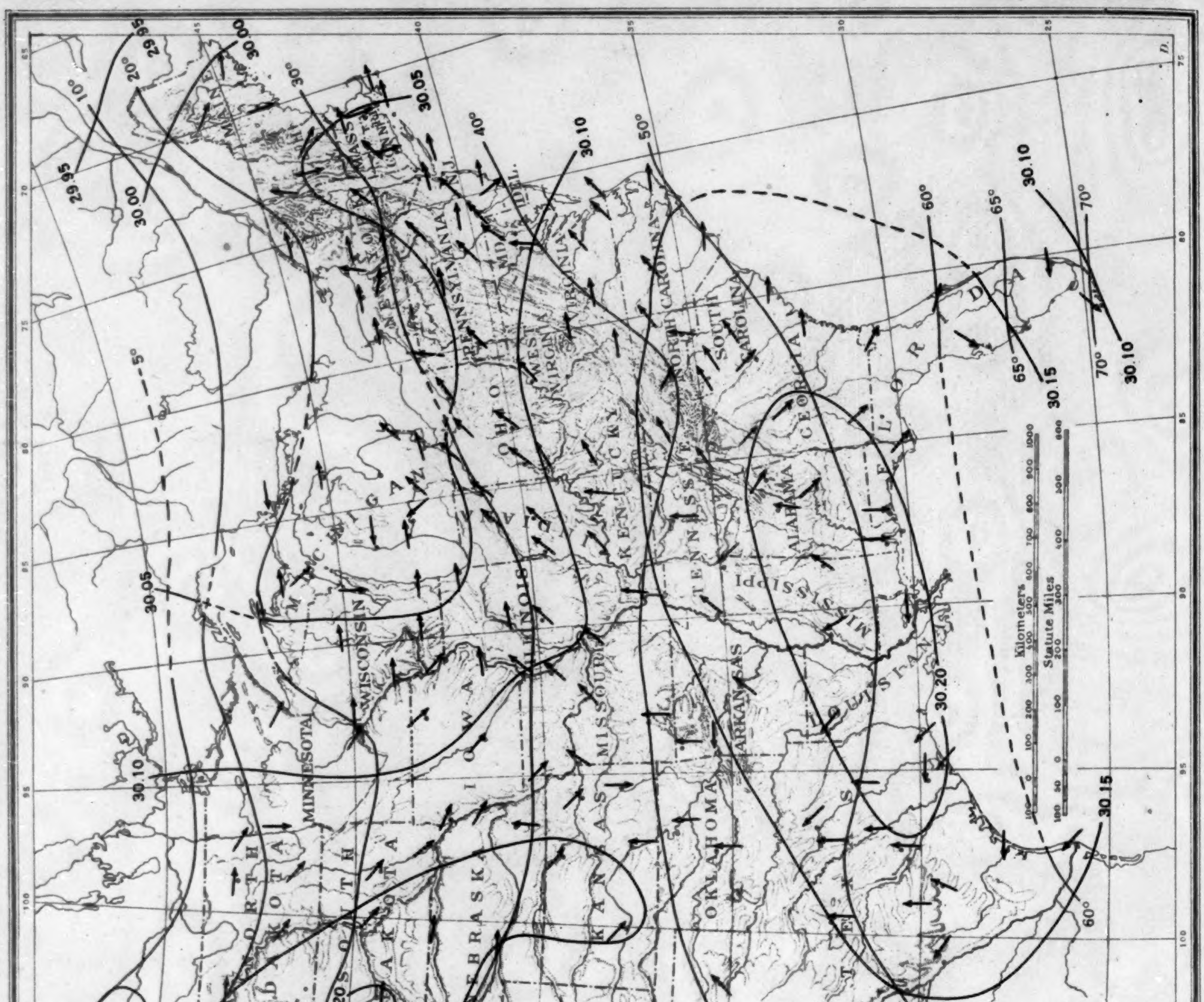


Chart VII. Total Snowfall, Inches, December, 1929. (Inset) Depth of Snow on Ground at end of Month

Chart VII. Total Snowfall, Inches, December, 1929. (Inset) Depth of Snow on Ground at end of Month

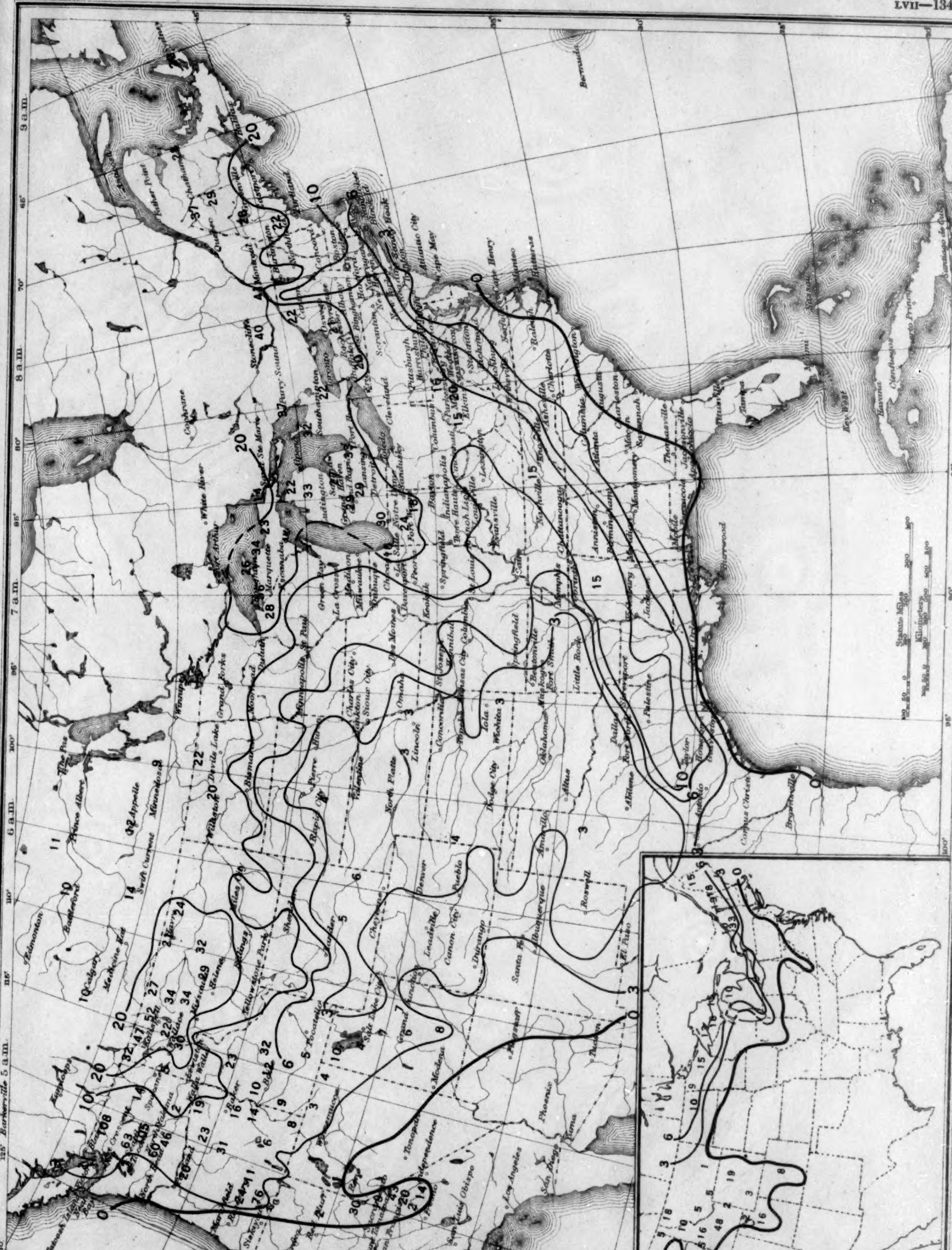


Chart VIII. Weather Map of North Atlantic Ocean, December 1, 1929
(Plotted by E. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, December 1, 1929

(Plotted by F. A. Young)

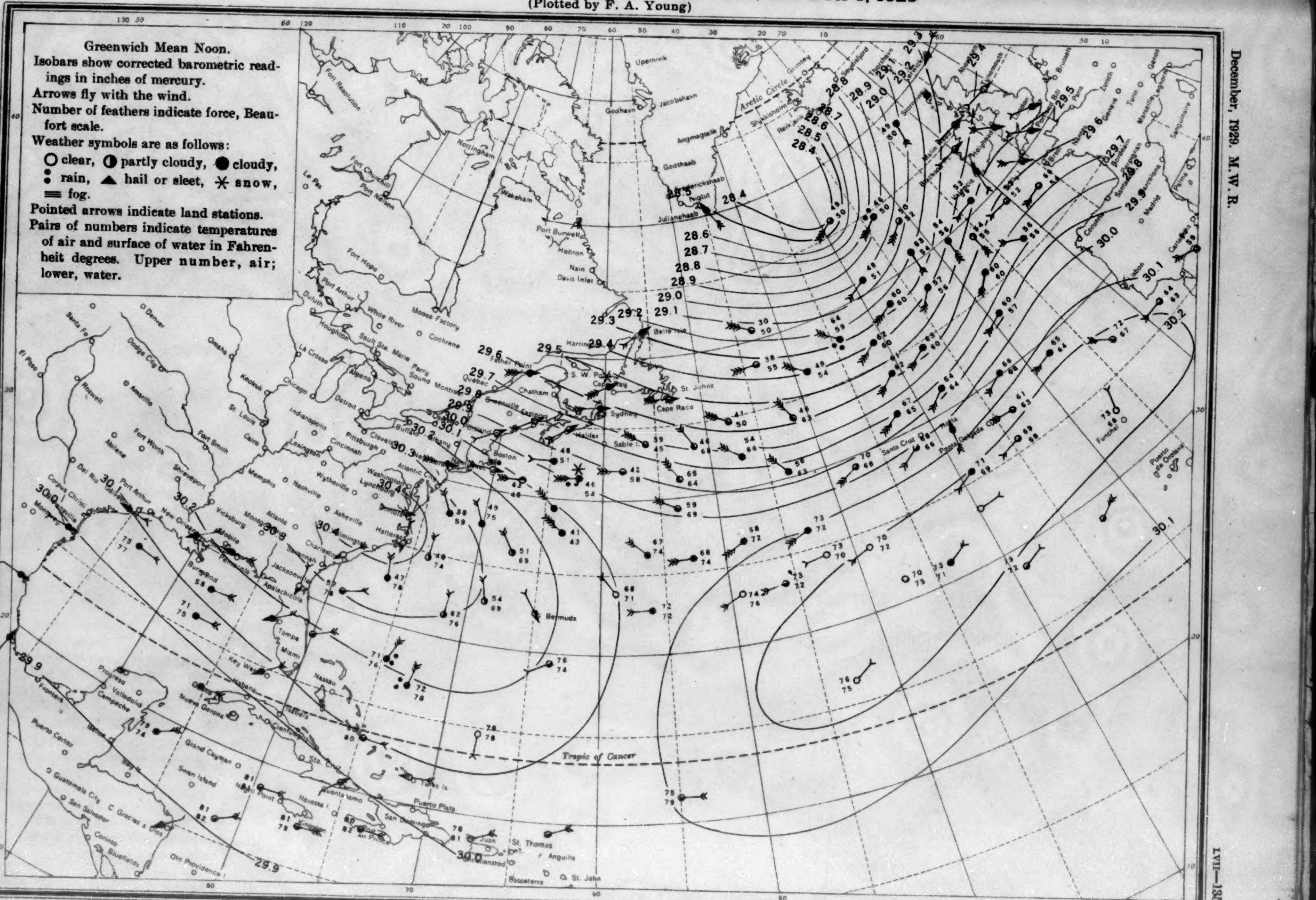


Chart IX. Weather Map of North Atlantic Ocean, December 2, 1929

(Plotted by F. A. Young)

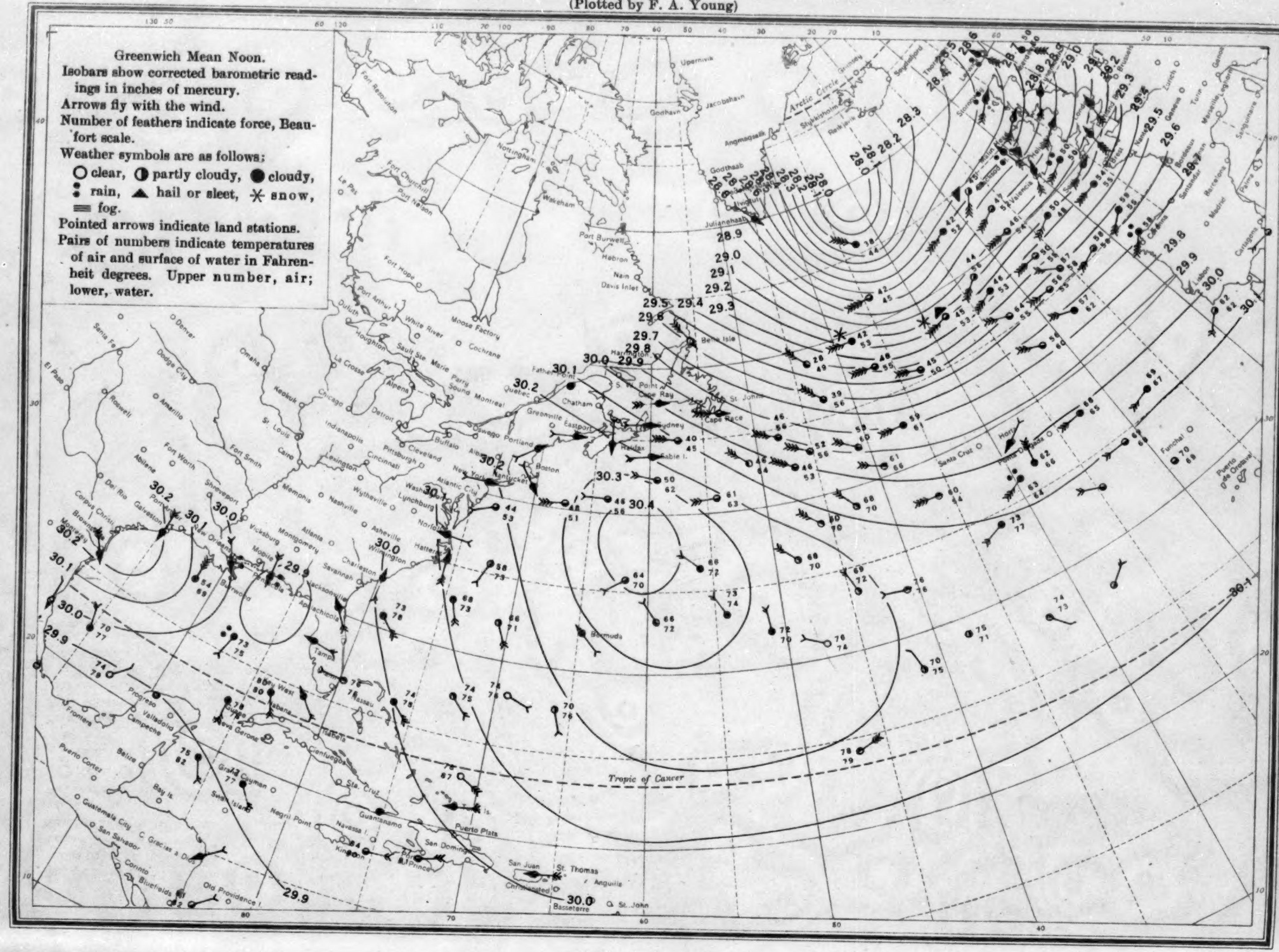


Chart X. Weather Map of North Atlantic Ocean, December 3, 1929

(Plotted by F. A. Young)

Chart X. Weather Map of North Atlantic Ocean, December 3, 1929
(Plotted by F. A. Young)

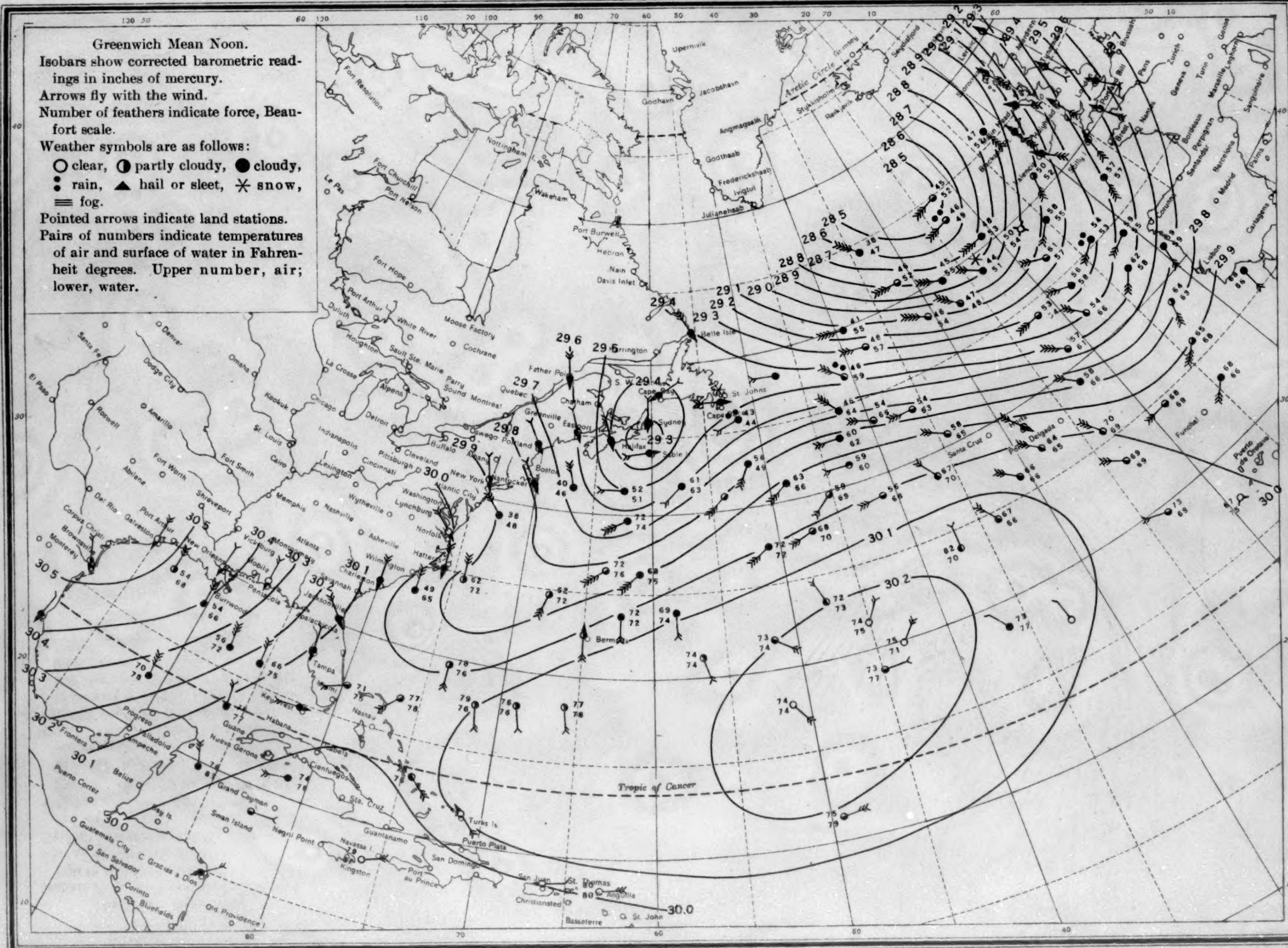


Chart XI. Weather Map of North Atlantic Ocean, December 4, 1929
(Plotted by F. A. Young)

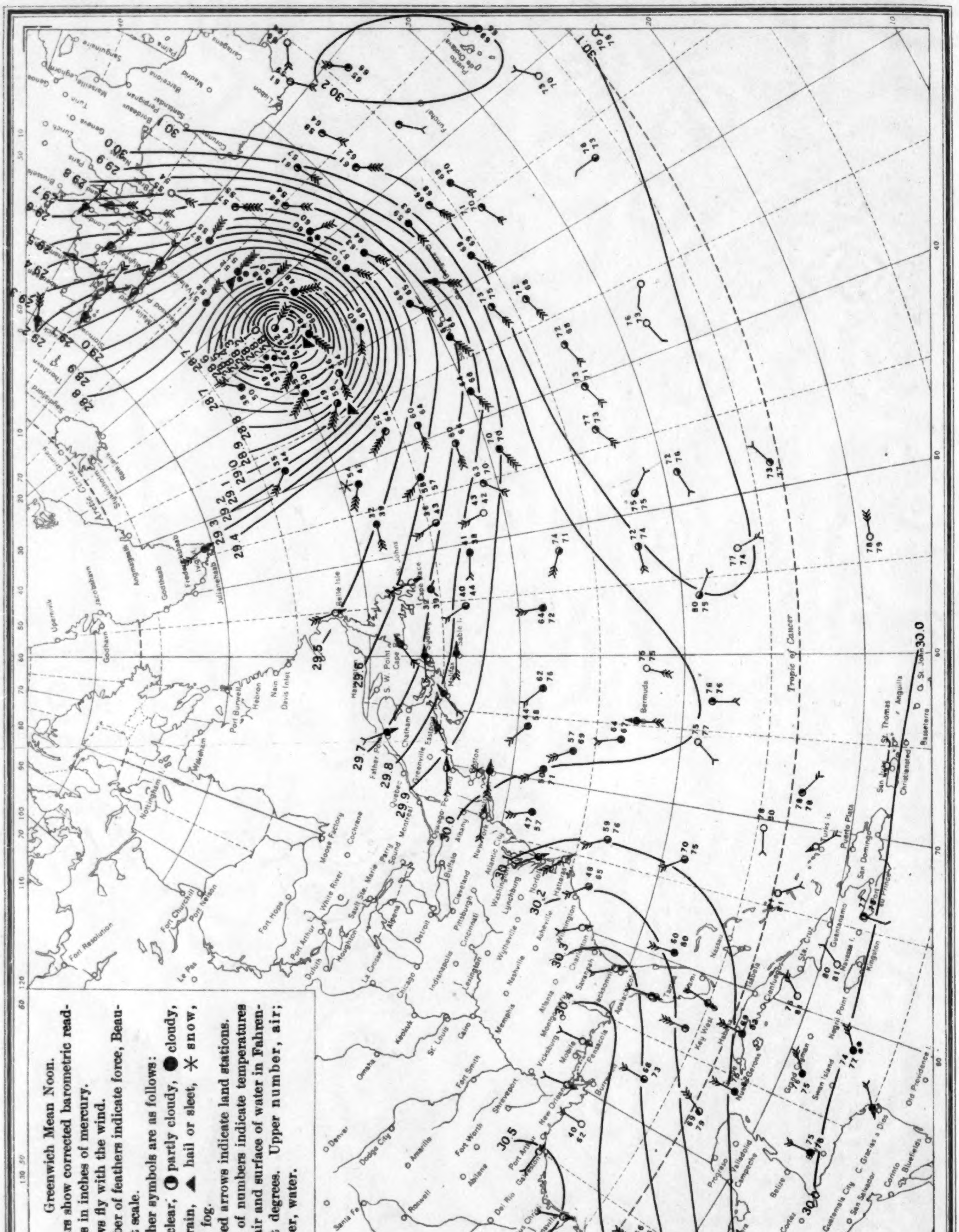


Chart XII. Weather Map of North Atlantic Ocean, December 5, 1929

(Plotted by F. A. Young)

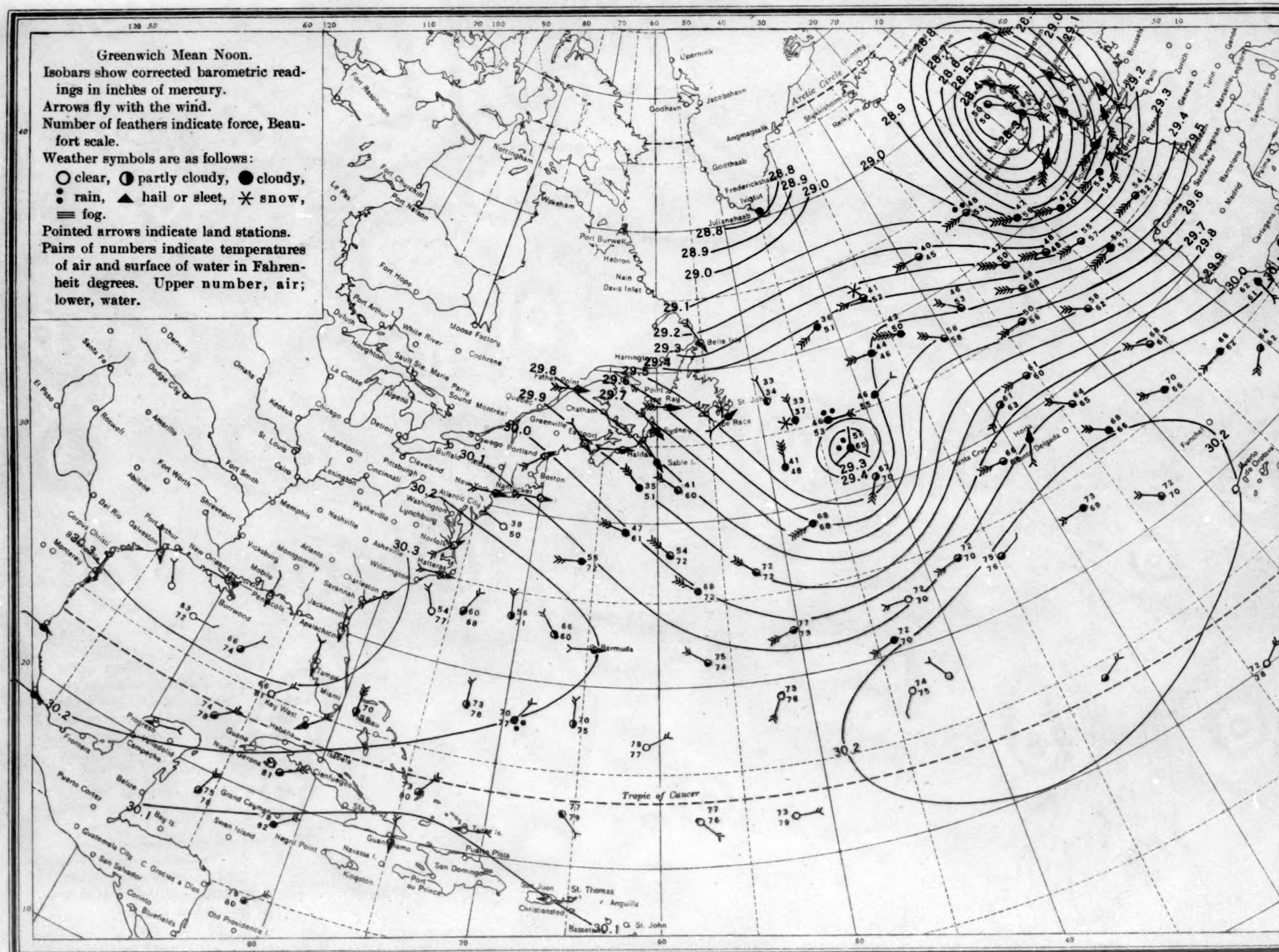
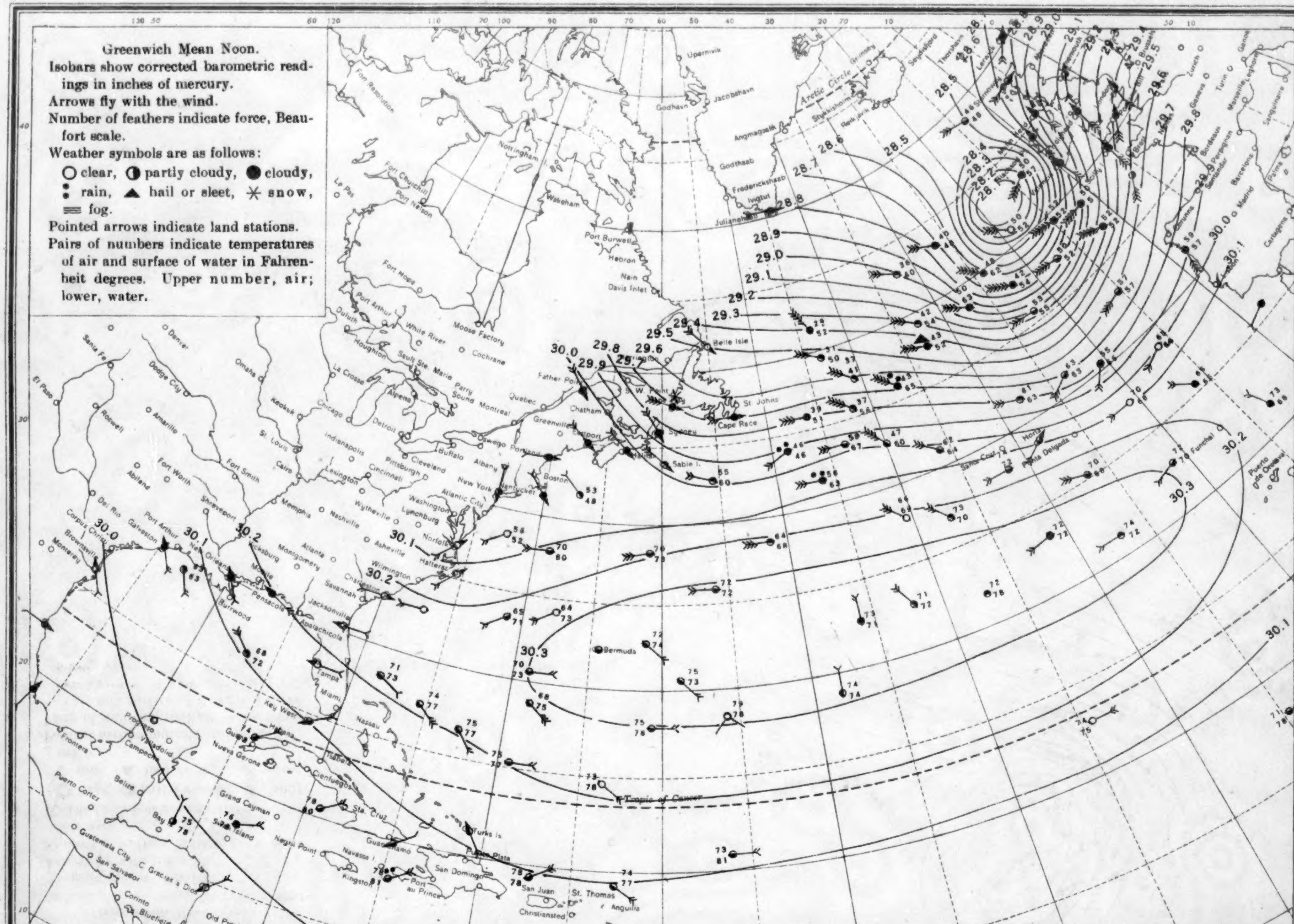


Chart XIII. Weather Map of North Atlantic Ocean, December 6, 1929

(Plotted by F. A. Young)



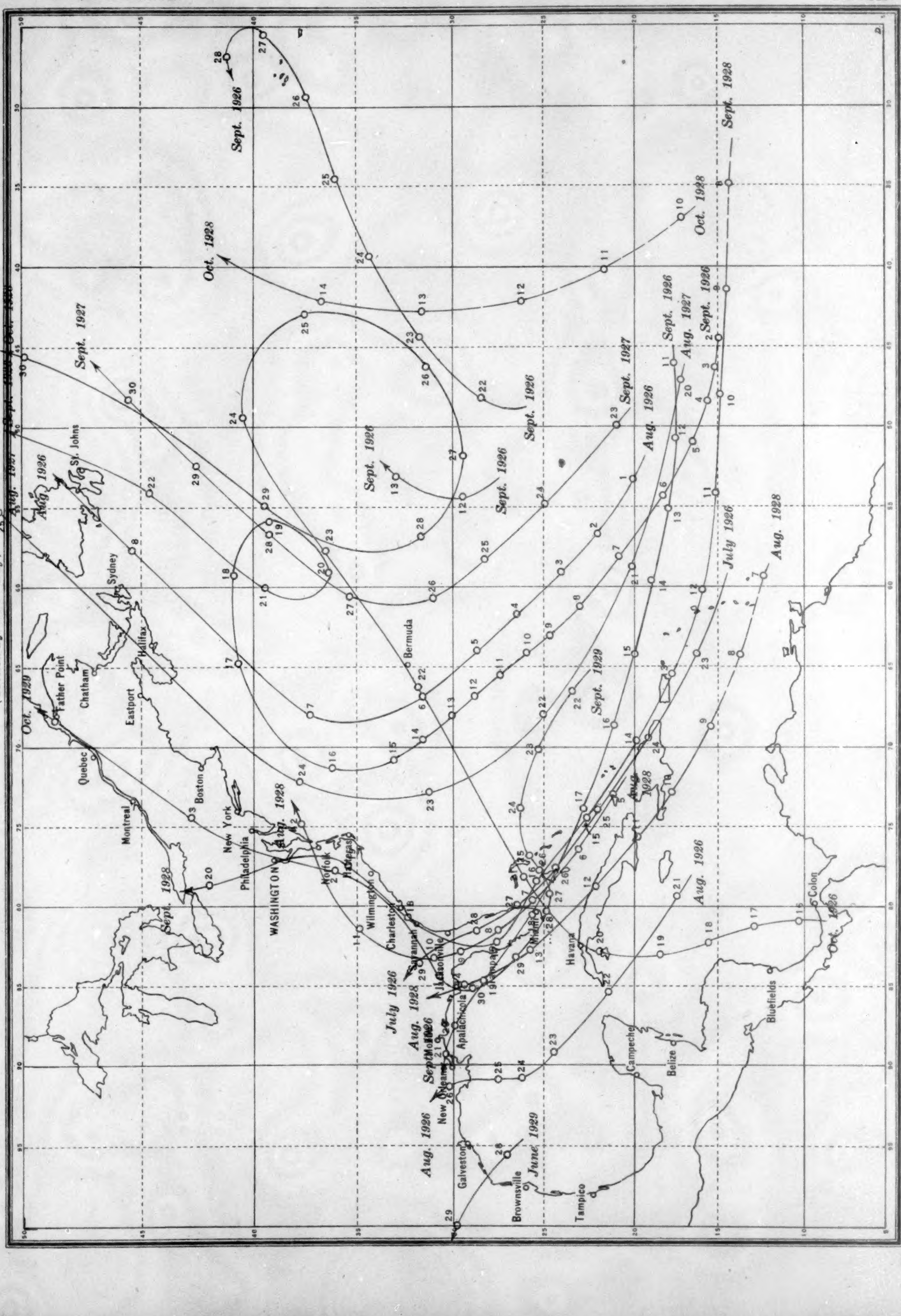
Tropical Storms of the Western North Atlantic, 1926–1929, Inclusive

(Taken largely from the Pilot Charts and limited to those of known hurricane intensity over some portion of path)

Tropical Storms of the Western North Atlantic, 1926–1929, Inclusive

(Taken largely from the Pilot Charts and limited to those of known hurricane intensity over some portion of path)

(Plotted by W. P. Day)



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